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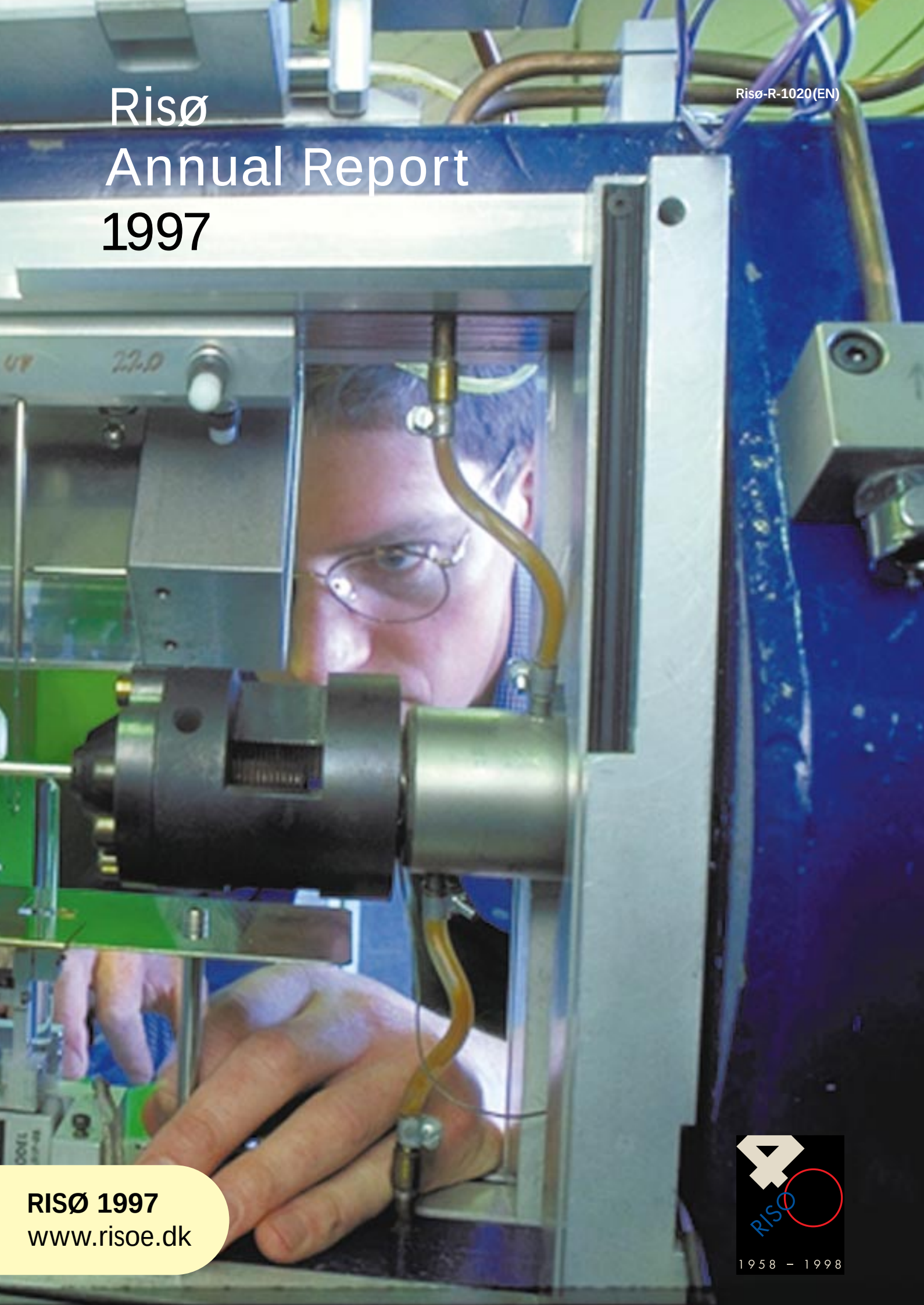

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Annual Report
1997

Risø National Laboratory, April, 1998

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Contents

The Chairman of the Board's Report

1997 was the final year of Risø's first four-year management performance contract with the Ministry of Research and Information Technology. The contract period was concluded by an extensive international evaluation. To the Board of Governors' satisfaction, it demonstrated that Risø had fully complied with the provisions of the contract and also demonstrated that contract management can be used for research institutions. The evaluation concluded that Risø's strategy is germane to Danish industry and that several of Risø's research departments are of great significance to Danish research scene in their relevant areas of specialisation.

In light of this and because, when all is said and done, the justification for the research community's existence is documented through the use that is actually made of its work, the evaluation recommended a number of different measures to improve Risø's transfer of knowledge and technology.

These recommendations were formed the basis of the Ministry of Research and Information Technology's written hearing of research councils, universities, industrial organisations, ministries, companies and institutions. The hearing was followed by a debate at Risø under the chairmanship of the Minister of Research and Information Technology.

Based on this, a new management performance contract was signed upon in the autumn. The new contract gives Risø satisfactory terms and financial conditions for the coming four years' work, and ensures that Risø will receive a net grant equivalent to slightly more than 50% of the total revenues. The remainder will come from participation in Danish and international research programmes and from research contracts with private companies. The contract positions Risø in the Danish research system and defines the most important research tasks in relation to the relevant national science strategies.

Like its predecessor, the contract sets targets that aim to ensure that scientific quality is maintained and that research continues to be renewed. It differs from the first contract, however, in that it also sets goals for development in Risø's relations with the industry, the research community, the technological service institutes and the ministries for which Risø acts as an adviser and supplier of knowledge in different areas.

Goals include formalised collaboration with the ministries, intensified research and educational collaboration with the universities and institutes of higher education, and a more rapid transfer of research results in collaboration with business and the technological service institutes.

This means that Risø will seek both to expand and make visible its participation in the education of M.Sc. and Ph.D. students in the natural and technical sciences, and to stimulate the development and innovation processes made possible by the research.

The expanded participation in development and innovation does not, however, mean that Risø must come up with new products itself – that would not be in accordance with Risø's charter. The challenge consists of going further into these processes without letting this affect the balance between, on the one hand, respect for private partners' needs for discretion and, on the other, the commitments which a public research institution must meet with regard to the publication of research results and maintenance of the basic research that is a prerequisite for quality and renewal.

Stock will be taken of the development in collaboration with Risø's partners and customers halfway through the new contract period. This will take the form of a report that will evaluate the effects of the new initiatives and determine any needs for adjusting the contract prior to the final evaluation scheduled for the start of 2001.

Risø's finances have developed satisfactorily in 1997. The attainment of the budgeted revenues is seen by the Board of Governors as confirmation that Risø's many employees have made a major effort and that thanks are due to them for this. The fact that the target revenues were also achieved confirms that Risø has maintained its competitiveness and ability to obtain free research funds.

In this connection, the Board of Governors considers it important to emphasise the significance of continuing free and open competition for these funds. This is the only way society can ensure that research is conducted by the best-qualified researchers.

Hans Bjerrum Møller retired on 1 October 1997 after ten years as Managing Director. Jørgen Kjems, who was initially Assistant Director and has served as Deputy Director since 1995, has replaced Hans Bjerrum Møller. The position of Deputy Director is expected to be filled during the spring of 1998, until which time Lisbeth Grønberg is acting as Deputy Director.

Hans Bjerrum Møller's commitment to Risø was a major factor behind the excellent evaluation Risø received in 1997. The Board of Governors would like to thank Hans Bjerrum Møller for his impressive and professional work.

Ulrik V. Lassen
Chairman of the Board

Photo: Michael Fischer

Professor Ulrik V. Lassen, M.D. Novo Nordisk Fonden.
Chairman of the Board.

The Managing Director's Report

With the completion of the management performance contract for 1994–97, Risø has complied with its overall goal of creating new development opportunities in those areas of Danish research in which it makes an independent contribution, and in which it can make its presence felt internationally.

Results

During the contract period, the materials research area has created possibilities for developing fuel cells that can convert hydrogen and natural gas into electricity, for producing optical and polymer sensors and sensor systems, and for developing new forms of plastic utilisation and plastic processing. Furthermore, in 1997 a material with previously unsurpassed capacity for the optical storage of data was also successfully produced.

The establishment of the RERAF experimental facility has enabled plant research to create opportunities for developing and testing agricultural plants with genetically engineered properties that reduce requirements for fertilisation, reduce the release of phosphor from manure, or otherwise lower the environmental impacts of plant cultivation. During 1997, the molecular biological knowledge on which this development is based also opened up unexpected perspectives for the production of plastic materials from biomass.

The Collaborating Centre on Energy and Environment that is jointly financed by UNEP, DANIDA and Risø, has won acclaim (most recently at the international climate conference in Kyoto) for a set of guidelines for calculating greenhouse gas emissions and the costs of limiting them. In the same programme area, a new programme for technology scenarios was inaugurated in 1997. Its purpose is to investigate and expand the scientific basis for predicting different effects of the uses of new technologies and to limit the uncertainties associated with their introduction.

In 1997, wind energy research completed the development of a model describing wind conditions over the sea, which is an important element in the theoretical basis for determining the optimal location of offshore wind turbines. An innovation of special significance to the wind turbine industry is the construction of a new hall at the Sparkær test centre for testing large wind turbine blades.

Nuclear safety research has concluded the development of methods for measuring and reducing radon radiation in homes. These methods have already been incorporated in official building guidelines. During 1997, all of Risø's nuclear activities were combined in the Nuclear Safety Research and Facilities Department, partly in order to prepare for a forthcoming change in generation.

The DR 3 research reactor continued to be utilised as a European user facility in the EUs Access to Large Scale Facilities programme, and Risø's participation in the work of planning a new generation of neutron sources passed a milestone when the *ESS – A Next Generation Neutron Source for Europe* report was published.

The international evaluation in the beginning of 1997 confirmed the high quality of Risø's research, as did the assignment to Risø of two centres under the Danish National Research Foundation (one for plant-microbe symbiosis research and the other for research into human-machine interaction) at the end of the year. Also, there is reason to mention the extension of the Engineering Science Centre for materials and models for another four-year period and the establishment of two THOR projects (one for the development of artificial muscles in collaboration with Danfoss and one for the development of methods to limit the formation of stems and flowers in grasses in collaboration with DLF-Trifolium).

Collaboration

These projects illustrate the interaction between Risø and Danish industry, much of which occurs through Danish and international programme research. In addition to this there are numerous large and small projects involving direct commercial collaboration. This form of co-operation, which is especially common in research into materials and wind energy, is to be intensified under the terms of the new management performance contract. This contract will also strengthen the transfer of knowledge and technology to the industry through the approved technological service institutes.

Collaboration with universities and other institutes of higher education typically occurs through joint participation in centre and programme research. An addition to this is educational collaboration, which in 1997 resulted in Ph.D. degrees being awarded to 27 young researchers – the greatest number ever in a single year. Ten of these were from Copenhagen University (KU), eight from the Technical University of Denmark (DTU), five from the Roskilde University Centre (RUC), one from the Royal Veterinary and Agricultural University (KVL), and one from Aarhus University, one from the University of Illinois and one from Cambridge University.

In this connection, there is reason to mention the creation of a graduate school, the Danish Ph.D. School in Non-linear Science, in collaboration with DTU, KU and Novo Nordisk; and a similar initiative in plant research in collaboration with KU, KVL, Odense University and the Danish Institute of Plant and Soil Science. The Danish Research Academy sponsors both of these schools.

Organisational development

In 1997, in order to implement its strategy and continue the development and innovation processes that are made possible by Risø's research results, Risø initiated a reorganisation to enable research to be supplemented by resources from the technical-administrative functions. Infrastructure functions will be maintained only to the extent that the authorities require them, or to the extent that they are better able to support research than external suppliers of equivalent services. As part of this reorganisation, which will reduce the infrastructure by approximately 60 man-years over a three-year period, Risø has leased the operation of its canteen to ISS Catering A/S and the operation of its electron accelerator to LR Plast A/S.

Risø's safety management has been reviewed for the purpose of reorganisation, so that the safety organisation can be adapted to the changes

made at Risø. This clarifies management's responsibility for safety and makes it a more natural part of daily work than had previously been the case.

Finally, an IT strategy has been prepared. This aims to improve the efficiency of Risø's use of information technology. Information systems, communication systems and administrative systems must be more closely integrated, and – simultaneously with the implementation of the new FØNIKS financial management system at the start of 1998 – a project will be initiated to develop standard solutions for a number of IT functions and make the necessary investments.

Risø's income from programme research and other contractual activities in 1997 amounted to DKK 222.1 million. This is equivalent to the budgeted income and represents a real increase of DKK 10 million compared with the previous year. The total result was a liquidity surplus of DKK 17.8 million, which is largely attributable to lower wage costs and the postponement of a significant outlay relating to the disposal of used reactor fuel. Among other purposes, the liquidity surplus will pay for postponed building investments during 1998. The larger investments in 1997 included setting up the Sparkær test centre and taking over the former CAT building at Risø which will now be fitted out as offices and laboratories for plant research.

The results of Risø's research in the past year are covered in more detail in the following pages and in the individual activity reports of the seven research departments. Together with Risø's Business Statement and the overview of publications, this information forms Risø's overall report on its activities in 1997.

Jørgen Kjems
Managing Director

Photo: Rigmor Mydtskov

Jørgen Kjems, Ph.D. Risø's Managing Director.

Industrial materials

Photo: Michael Fischer

Dorte Juul Jensen became Denmark's first female Doctor of Technical Sciences. She is seen here with the department's scanning electron microscope which, among many other things, is used to determine crystallographic orientations in selected areas of samples.

New materials are a decisive prerequisite for improving the utilisation of resources, reducing harm to the environment and increasing Danish competitiveness in the areas of energy technologies and industrial processes and products. Risø's industrial materials programme aims to contribute to Danish society by opening new opportunities through basic and applied research into materials.

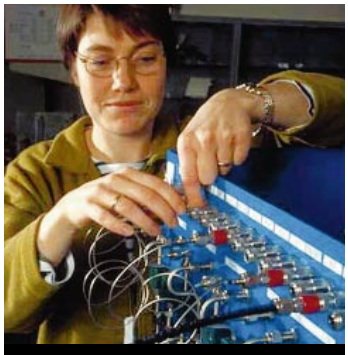
In order continually to be able to meet industry's needs for materials with new and more advanced properties, the programme performs long-term research into the structure and characteristics of materials. An example of this research is the study of the reactions of metals to heat processing that led, in 1997, to Risø researcher Dorte Juul Jensen becoming Denmark's first female Doctor of Technical Sciences. Her work is of practical interest to industry both in Denmark and abroad, where several of the techniques developed have already been utilised. In addition, two large foreign aluminium companies have started implementing the models she has developed for the simulation of hot rolling of aluminium.

The optimal industrial utilisation of materials for new purposes requires highly detailed knowledge of material structures. In co-operation with ESRF, the department has therefore started a project for the design and construction of a large research facility to study structures and structural changes, e.g. during deformation. Present methods in this area are suited to structures in and near the surface, but use of high-energy X-ray radiation from a synchrotron makes it possible to 'see in depth'. The equipment is expected to be operational during 1998.

Another way to acquire new basic knowledge about materials is to employ electron microscopy. In 1997, a number of important results in the study of single crystals, polycrystals and thin films were achieved. Among these was the development of a new method to correct for scattering effects in chemical analysis using X-ray spectrometry in the department's Environmental Scanning Electron Microscope (ESEM). The internal stresses of polycrystalline materials and composite materials are important for strength, formability and endurance. A number of successful experiments have been performed using complementary techniques that make use of neutron, X-ray and electron radiation, respectively.

An important link between industry and research is the Engineering Science Centre, the operating period for which was extended in 1997 by a new five-year term up to 2002. The STVF has committed a total of DKK 22 million to the centre's operation, with the largest part of this sum being set aside for the education of scientists.

Photo: Michael Fischer



Mixing gases for the electrochemical testing of solid oxide fuel cell components.

The composite-consuming industry is generally interested in finding alternatives to traditional fibreglass materials that give rise to a number of problems in production processes and the working environment. Interest in using natural fibres is therefore increasing. In collaboration with KVL and DTU, an extensive programme for the production and use of plant and tree fibres was started in 1997. The department's efforts are focused particularly on characterising and developing composite materials with plant fibres. During 1997, plant fibre composites have been produced from fibre mats of jute and flax. Subsequent characterisation has shown that the quality is good, as the plant fibre composites display stiffness values and strength comparable with fibreglass composites. In addition to plant fibre composites, interest is also accumulating around fibre-reinforced thermoplastics and, as part of a long-term aspect of development, in 1997 Risø joined a company to develop forming tools for producing wind turbine blades from fibre-reinforced thermoplastics.

A successful collaboration in MUP with three Danish companies was concluded in 1997. The aim was to develop thermoplastic fibre composites, e.g. for wind turbine blades and automotive components.

Risø is developing powder metallurgy in which the metal is formed by sintering very fine-grained metal powder. Among other things, this requires the development of new metal alloys and, in 1997, work has been done on characterising suitable alloys. As an extension of this technology, collaboration has begun with the Danish Steelworks Ltd. to develop spray forming for producing metallic composite materials containing ceramic particles (MMC). This collaboration, in which DTI and a number of industrial companies are involved, is taking place as part of a centre contract with the Danish Agency for Trade and Industry.

Fuel cells can convert gaseous fuels such as natural gas, coal gas,

Photo: Boye Koch

X-ray setup for detecting ceramic voids inside the silver sheath of superconducting tapes.

biomass gas and hydrogen directly to electrical power using atmospheric oxygen. The great flexibility of these cells will make them well suited to the energy systems of the future. One of the goals in the management performance contract 1994–97 with the Ministry of Research and Information Technology for the production of 500W from a cell stack was fulfilled in 1995. In 1997, emphasis was placed on the further development of fuel cells that operate with natural gas, and the implementation of a test stand for solid oxide fuel cells (SOFCs) with internal reforming of natural gas is now approaching a conclusion. The research is supported by the Danish Energy Agency and is continuing in co-operation with several universities and Danish industry.

Superconducting high-voltage cables are being developed in a collaborative venture between NKT and Risø, DTU and DEFU. The project is supported financially by the Danish Energy Agency and ELKRAFT (an electrical utility). NKT produces the superconducting tape and is designing the electrical cables together with DTU. DEFU is studying the possibilities for utilisation. Risø is performing the basic research in superconductivity and is developing methods for characterising the tapes and for improving production conditions. The preferred superconductor for superconducting cables is a ceramic material called BiSCCO that is filled into thin silver tubes. Each tube is sealed, stretched, rolled, pressed and heat-processed so that it becomes a flat tape. A production line has now been set up at Risø where 10 metre long tapes can be manufactured, and detailed studies of every single step in the process can be performed. During 1997, Risø has worked in particular on the development of a method for the profile rolling of the silver tubes for the purpose of identifying a method that can be used in industrial production.

Highly effective flywheels offer an attractive potential for energy storage and opportunities in the transport sector are particularly promising. A prototype flywheel is now under construction at Risø. The project is being implemented in collaboration with NESA A/S, Per Udsen Co. and DEMEX A/S and is financed by the Danish Energy Agency.

In the long-term, the area of fusion energy poses major requirements on materials research. Risø is investigating the effects of radiation on the durability of materials. In 1997, among several areas for the ITER project, Risø performed studies on the effects of heat processes on the mechanical and physical properties of copper alloys in fusion equipment subjected to radiation at different temperatures. The ITER project aims to demonstrate scientifically and technologically the practical applicability of thermonuclear fusion in energy production.

In both the energy and industrial sectors, Risø actively participates in EU research programmes. This is especially so in BRITE-EURAM and JOULE-THERMIE, where Risø manages projects in areas such as composite materials, non-destructive testing, forming processes and fuel cells.

The industrial materials programme is based in the Materials Research Department.

Key figures in 1997

In 1997 the department engaged 105.2 man-years, 14.1 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 70.0 million, 33.6 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Research programmes, etc.
BRITE-EURAM · Danish Agency for Trade and Industry, Centre Contract · MUP · SNF · STVF · IVC · EFP · EUCLID · EU-Fusion Technology Programme · EUREKA · ITER R & D · JOULE-THERMIE · LIP· New Energy Development Organisation, Japan · Nordtest

Private Danish companies
A/S Hartfelt & Co. · A/S Kaj Neckelmann · APV Pasilac A/S · Bonus Energy A/S · Carl Bro Industri & Marine A/S · Danfoss A/S · Danish Steel Works Ltd. · Dansk Sintermetal · DEMEX A/S · ELSAM · Ferritslev Jernvarefabrik A/S · Ferroperm Components Division of AMP · Grundfos A/S · Haldor Topsøe A/S · Innovision A/S · Komposit Procesteknik ApS · Kuwait Petroleum A/S · LM Glasfiber A/S · NESA A/S · NKT Cables A/S · NKT Research Centre A/S · Nordic Superconductors Technology A/S · Norsænk-Aalykke A/S · PBI-Development A/S · Per Udsen Co. · Research Assoc. of Danish Electric Utilities · Roulunds A/S · Scan-Visan A/S · Vestas A/S

Private foreign companies
AEA Technology, Harwell · Aerospatiale SA · Allied Signal Bremsbelag GmbH · Blankguss · Bosch Systemes de Freinage · British Aerospace – Airbus · Bundesanstalt für Materialprüfung · CEIT de Guipuzcoa · Centro Richerche FIAT SCpA · Daimler Benz GmbH · DSM · ECN, Petten · EFU GmbH · EMPA · EPFL · Fagor Ederlan, S. Coop. Ltd. · FIAT SpA · Frauenhofer · Garrad Hassan & Partners, Ltd. · Gaz de France · GF Automobilguss · GIE Renault · Gränges AB · ILFB/ TU Wien · IMMG · Impactor Technology AB · INPG · Institut de Soudure · Instituto de Soldadura e Qualidade · ISRIM · Kemijoki Yo · LKR, Ranshofen · Morgan MT · NFL (Studsvik) · Norsk Hydro (Mg Division) a.s. · Norsk Hydro Aluminium a.s. · NUVL · OTO Melara · Pechiney CRV SA · Photonic Science plc · Ranshofen · Rolls Royce – Gas Turbines · Rolls Royce · Rover Group Ltd. · RWTH-Aachen · Sauerwein Systemtechnick GmbH · Schunk Kohlenstofftechnik · SEPARIS · Shockwave Metalworking Technology · Siemens GmbH · Sintech Keramik · SINTEF · Stampal SpA · Statoil a.s. · Thomsen Tubes Electroniques SA · TNO Research Centre · TYK Corporation · Unitech · Volkswagen GmbH · Volvo AB

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New functional materials

The programme aims to create new technological opportunities for Danish and European industry through research into the fundamental properties of materials. Many of the projects are performed in collaboration with research-oriented industrial companies. Efforts focus on structural characterisation using neutron and synchrotron radiation, the study of the physical and chemical properties of new materials, and the synthesis of polymers and macromolecular materials.

The need of the polymer industry for research and development has led to the establishment of the Danish Polymer Centre four years ago. The DPC is a collaborative venture between a number of private companies, the DTU and Risø, which co-ordinates the activities. The centre is supported by MUP2. Most of the industrially oriented polymer activities in the department area take place within the framework of the centre. The centre's budget allocation period ends on 1 July 1998 and efforts are being made to arrange a continuation of its activities.

Industrial applications of polymers has led to requirements for polymer materials to be customised for specific purposes, e.g. adhesives, sealants and insulation materials. This can be done by mixing two or more polymers, each of which contributes with specific properties. The problem is that such polymer systems are not normally miscible. On the other hand, this leads to self-organisation in which the molecules spontaneously form well-defined aggregates and crystalline phases. This behaviour opens completely new technological opportunities.

The polymer industry is especially interested in the opportunities to be found in the block copolymers that are already being marketed for use in, e.g. paints, windows and protective films. For industrial purposes, it is important that the materials are stable with regard to temperature. Risø is therefore studying water-based solutions of block copolymers based on polyethylene oxide which have exactly this property, because aggregates are created in a glassy form at a certain temperature. Above this temperature, the materials become soft and can easily be processed in different ways by utilising shear fields.

Risø is investigating the opportunities for applying these glassy states with Raychem Co., an American polymer company, and with Leuven University in Belgium. A system that can create a thermoplastic elastomer jelly that can easily be processed above the glass-transition temperature using shear fields is being developed. In 1997, it was demonstrated that shear processing can produce very special elastomers with a single crystalline phase.

Another area of great industrial interest is the production of block copolymers with properties like those of ordinary surface-active agents (surfactants) that are used for soaps and viscosity control. This attractive, homogenous sponge-like microemulsion phase has not previously been seen in purely polymer materials. In collaboration with universities in the USA, Risø identified such phases in complex polymer compounds for the first time in 1997. Polymer materials also have bearing on an important problem in robotics. 'Muscles' that can bring robotic movements closer to those of human are still being sought. Risø is cooperating with Danfoss A/S and DTU in a three-year THOR (Technology by Highly Oriented Research) project to develop polymers as electrically controlled actuator materials for artificial muscles. The first designs for such actuators have already been prepared.

The information technology industry is making increasing demands on the capacity of information processing and storage systems. Whereas magnetic media are approaching the limits of their capacity, there is so far unused potential in optical media. Risø is therefore working with photoanisotropic molecular materials for optical information processing. During 1997, this work resulted in greatly improved properties of these materials, in the development of a model that explains their properties, in their simplification and thus improved cost-effectiveness of their production and finally in a patent application. Agreements for R&D cooperation with industrial companies are expected in 1998.

As mentioned, magnetic storage media are approaching the limits of achievable information density, as Risø demonstrated in 1997. High information density requires small particles, but in nano-sized magnetic particles the direction of the magnetisation can fluctuate spontaneously. This phenomenon, known as superparamagnetic relaxation, makes the particles unsuitable for information storage. Researchers from Risø were

Foto: Boye Koch

Rheometer on line small angle neutron scattering instrument, where mechanical and structural data are obtained simultaneously, and where structural response to mechanical displacement can be studied.

the first to observe this phenomenon directly in 15-nm particles of the iron mineral hematite.

The EU neutron user programme aims to ensure the use of Risø's research reactor DR 3 as a national and international facility for research in neutron scattering. The programme addresses both Danish and European needs. The DR 3 reactor with its related neutron-scattering equipment is a part of the collective EU pool of large research facilities. With support from the EU TMR programme, Risø makes facilities available for and co-operates with approx. 100 EU researchers each year. Compared with light or X-ray sources, neutron sources are generally very weak. The development of a methodology and instrumentation along with new and better sources is an important aspect of the programme. The construction of a new spectrometer, RITA, has just been completed, thus fulfilling the goal for that area in Risø's management performance contract for 1994–97 with the Ministry of Research and Information Technology. Risø also participates in joint European R&D in connection with ESS – the European Spallation Source – that is aiming by 2000 to present European governments with the basis for a decision on the construction of a spallation source. It is anticipated that the source itself will be completed between in the period 2005 to 2010.

In line with the technological development of nanotechnology, there is a need to establish facilities for research into epitaxial growth of molecular surface layers for electronic, optical and tribologic purposes. In 1997, Risø therefore began building activities in this area. Studies of surface phenomena using neutron and X-ray scattering methods have been supplemented by Scanning Probe Microscopy (SPM). In SPM, a needle of molecular dimensions is moved over the sample surface much like the pick-up of a gramophone to draw an atomic and molecular three-dimensional picture of the surface. Many of the SPM tasks are concerned with organic polymers of industrial interest. An example is the control of protein adhesion to synthetically produced surfaces. In 1997 Risø collaborated with a company on the production and characterisation of closely-packed single layers of molecules on silicium oxide surfaces that are able to prevent the adhesion of proteins. The measurements are surprising in that greater coverage is achieved on a surface by reducing the concentration of the reactant in the process solution. This was shown to arise primarily from space problems.

There are also needs in other technological fields for attaining a deeper understanding of the behaviour of surfaces and interfaces. An example is the production of new semiconductor devices consisting of several layers. They are technologically interesting because they enable components to be produced that function in three dimensions instead of just two. Direct adhesion of thin wafers is expected to be a key technology for microelectronics and micromechanics in the coming years. For Topsil Semiconductor A/S, Risø has demonstrated what happens to atoms in the interface between the two wafers. Work is now being performed on clarifying the relationship between this and the electrical characteristics of the interface. These studies have been made using the X-ray radiation of the European and Hamburg synchrotron radiation facilities (ESRF and HASYLAB respectively).

Since the discovery of high-temperature superconductors 10 years ago, there have been major industrial and research efforts to understand the fundamental properties of these superconductors and develop them for practical use. The so-called magnetic flux-line lattices are important in this relationship and Risø's studies in 1997 have led to important scientific results in this area regarding the material $TmNi_2B_2C$.

Risø is also co-operating with NKT in the study of the relationship between texture and critical current in BiSCCO/Ag superconducting wires.

Photo: Michael Fischer

An AFM (Atomic Force Microscopy) microscope can display 3D atomic pictures of surfaces.

The programme area for new functional materials is based in the Condensed Matter Physics and Chemistry Department.

Key figures in 1997

In 1997 the department engaged 63.2 man-years, 21.3 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 44.4 million, 15.9 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.

EU (DG XII and DG XIII) · Ministry of Research and Information Technology · Ministry of Environment and Energy · SNF STVF · Danish Academy of Technical Sciences · Danish Research Academy · NATO · Carlsberg Foundation

Private companies
Danish
Danfoss A/S · Novo Nordisk A/S · NKT A/S · Grundfos A/S · Coloplast A/S · Nunc A/S · Hempel Marine Paints A/S · Radiometer A/S · ABB · I.C. Møller A/S · M&E A/S · Medico Chemical Lab

Foreign
Mallinckrodt · Philips · Optilink

The department also co-operates with a number of Danish and foreign universities and public research centres in research and instrument development.

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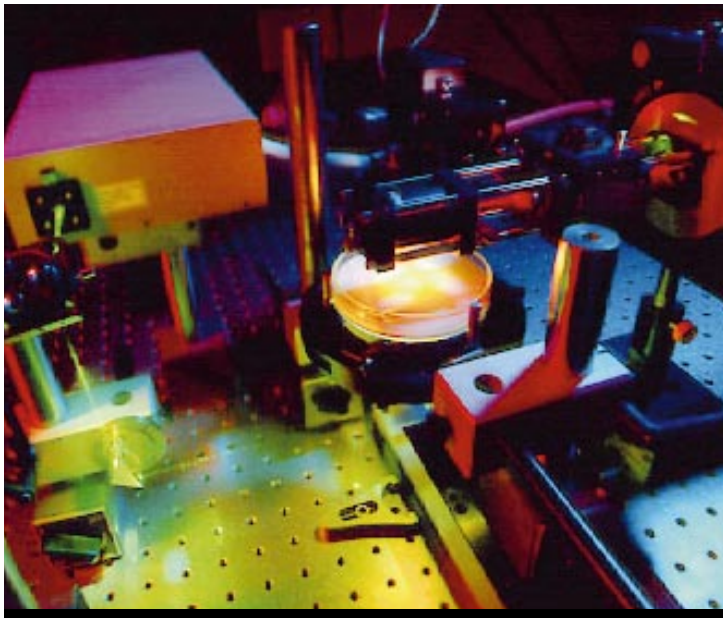
Optics and sensor systems

Photo: Boye Koch



Experimental setup for opto-acoustic imaging of deeply buried absorbing objects in highly scattering media, i.e. phantoms that model malign tumours in human tissue.

Industry's need for new types of miniaturised optic systems for measurement, information storage and energy-effective image and pattern generation provides the basis for Risø's research in optics and sensor systems. The programme area covers optical diagnostics and modelling of diffraction and non-linear optics, fusion plasmas and special microflow systems.

The industrial use of optical sensors based on microoptics requires compact and robust implementation. A high degree of sensing accuracy is often needed. In collaboration with Dantec Measurement Technology A/S, Risø started these industry-oriented activities several years ago with the development of an optical sensor to be used in production processes for noncontact measurement of paper speed and length. System concepts for a number of optical sensors have since been developed at Risø. The development of technologies that facilitate the extreme miniaturisation of optical sensors is one of the core elements in the programme area. A very important new activity is the investigation of polymers for integrated optical systems.

Several projects for industry have now been commenced in the areas of mechanical motion, quality control of products in the health-care area, polymers for optical components, materials and structures for visualisation purposes and optical processing of plants as an alternative to chemical methods. Risø is co-operating with several companies in the CAT Science Park. An example of this is a joint project with Jan Steensborg and several companies in the graphics industry in which microprofiles in surfaces for producing special graphic effects are being developed. With the commercial production of holographic optical elements by the CAT companies Ibsen Micro Structures A/S and Jan Steensborg, and the production of different types of measuring equipment at Dantec Measurement Technology A/S, Risø fulfilled one of its result goals in the 1994–97 management performance contract with the Ministry of Research and Information Technology.

Industrial needs for developing optically based measuring methods to determine mechanical parameters are being addressed partly through a framework project (LIS) under the management of the Microelectronics Centre at the DTU and partly through external commercial financing. This work has led to applications for two patents. Methods for very energy-efficient pattern generation with applications to labelling and image projections are being investigated in a joint effort with Hamamatsu Photonics in Japan. A joint patent application based on a previous Risø invention has been submitted.

Optical methods are of increased interest in medical diagnostics. One of the major objectives is to replace blood tests for measuring blood sugar or cholesterol levels, for example, with small measuring probes placed on the skin, which cause no discomfort to the patient. Knowledge about light propagation and scattering in human tissue is important for localised diagnostics. This knowledge also has important applications in connection with laser treatment, e.g. for the removal of birthmarks, treatment of eye diseases and tumour removal. Together with Bang & Olufsen Technology, Risø has been working on optical glucose sensors. The results of the collaboration are models explaining the physics of the basic measuring method as well as applications of the models for predicting scattering of propagated light and scattering in human tissue. The models pave the way for optical measurements in connection with other types of medical diagnostics, and in 1997 Risø has expanded the theory for use in more demanding applications such as mammography. Close co-operation was established with Herlev Hospital, the University of Aarhus/Marselisborg Hospital and industrial companies in the fields of medical diagnostics and lasers; this resulted in medicinal optics being established as an important activity in 1997. Parts of this work are supported by the STVF.

The understanding of biomedical flows is important both for diagnostics and treatment. A collaborative effort with UNI-C (Danish Computer Centre for Research and Education) and the Microelectronics Centre has been established. Within the area of scientific computing new methods for analysing such flows are being developed. The transport of biological cells in microchannels is being investigated.

Short development times are decisive in connection with industrial products. This requires the development of effective methods for calculating the design of miniaturised optical sensors. There is a need to improve the theoretical basis particularly in cases of extreme miniaturisation. The goal is to be able to design surface holograms on waveguides for making noncontact measurements of different physical parameters such as mechanical motion, chemical composition or physical state. In collaboration with Brown University (UK), Risø has developed a new numerical method that has already demonstrated very promising results. To be able to transfer calculations to components, the production of very highly detailed patterns is mandatory. Good results have been achieved using a holoplotter developed at Risø, but the resolution is inadequate for generating very small structures. An investigation has begun to find methods for achieving very high resolutions.

Miniaturised optical systems of the type discussed here pose completely new requirements to materials and production processes. Risø has therefore entered into a systematic study of the use of polymer materials and has achieved good results with new production methods in collaboration with a Danish industrial company. It has been demonstrated that the methods used to produce compact disks can also be used to make highly complex integrated optical components.

Integrated systems often necessitate electrical connections via materials that must simultaneously be current-conducting and transparent. Indium tin oxide is a material with these characteristics. Risø is working on the production of very thin films based on laser ablation.

In connection with the EURATOM collaboration in the area of fusion energy, a new diagnostic method based on the use of light from a carbon dioxide laser has been developed. The first measurements using the new laser diagnostics have been made in the W7-AS stellarator in Garching, Germany. The work with carbon dioxide lasers has resulted in activities with a completely different use: the measurement of wind velocity in front of a wind turbine for the purpose of controlling the turbine and effect curve measurements. This work is being performed in collaboration with two private companies, one of which is located in the CAT Science Park. A patent application has been submitted for the new method. The continuing work is expected to be supported by the EU.

The monitoring and control of systems for incinerating special biomasses calls for advanced measuring methods and Risø is working on the development of infrared spectroscopy for this purpose. Initial work has demonstrated new opportunities for using this technique and Risø has been invited to participate in a large European research programme project together with, among others, Deutsche Forschungsanstalt für Luft- und Raumfahrt and British Aerospace.

With this range of initiatives and results, Risø is well on its way toward playing a leading role in the expansion and co-ordination of optical research in Denmark, with utilisation perspectives in, e.g., biomedicine as well as in industrial sensor and measuring techniques.

Robots and process monitoring are important in production lines and Risø is involved in EU projects that require image processing using neural networks. 1997 saw the completion of a project in which image material from the incineration zone in a waste-incineration plant was applied to define a procedure for achieving optimal efficiency and reduced emission of toxic gases. In another project, work has been performed on robotic visual recognition of special components in electronic equipment. This will enable the automatic separation and removal for either recycling or environmentally friendly destruction.

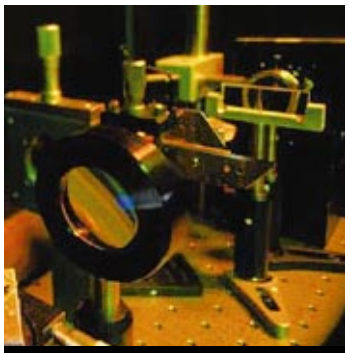


Photo: Boye Koch

A laser diode array with phase conjugate feedback.

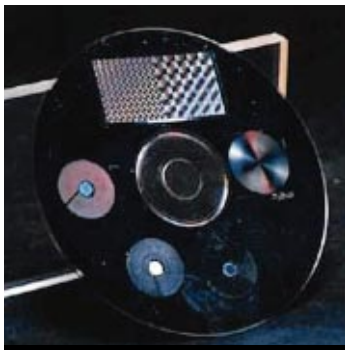


Photo: Boye Koch

CD with diffractive elements. The CD represents a breakthrough for SDC-Dandisc and Risø, as this is the first time standard CD production technology has been applied to the mass-production of small, complex optics.

The optics and sensor systems programme area is based in the Optics and Fluid Dynamics Department.

Key figures in 1997

In 1997 the department engaged 52.8 man-years, 14.7 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 35.0 million, 11.2 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.
EURATOM · ESF, TAO programme · EU's environmental programme · ESPRIT · INTAS · NATO · STVF (Danish Technical Reserach Counsil) · SNF (Danish Natural Science Research Council) · EFP (under the Danish Ministry of Environment and Energy) · EUREKA (under the Danish Agency for Trade and Industry) · Danish Research Academy · Hewlett Packard (donation of workstation) · UNI-C (co-financing of Ph.D. students)

Private companies
Danish
Dantec Measurement Technology A/S · IBSEN Micro Structures A/S · Nordic Laser Systems A/S · Giga A/S · DanDisc A/S · Torsana A/S · SignTronic A/S · Ferroperm A/S · Scanvision Screen · Intellix A/S · Infoteam A/S · KANI Tech A/S · Regstrup Vision · Scan Technology · Aalborg Sunrod · ReaTech, CAT · Bang & Olufsen Technology · Unisensor · DTI · Vestforbrænding I/S · SK Energy · B&W Energy · Rockwool International · Tillqvist Proces A/S · Foss Electric A/S ·

Foreign
Siemens · NASA · Anacad Electrical Engineering Software SARL · Hamamatsu Photonics · Thompson Training and Simulation Optilink AB · British Aerospace · Mittateknikan Keskus · Swedish National Testing and Research Institute · Sensor Partners · Sick AG

The department also co-operates with a number of Danish and foreign universities and public research centres.

www.risoe.dk/ofd

Plant production and ecology

Photo: Michael Fischer

Equipment for NMR spectroscopic studies of nitrogen fixation in living plant-microbe symbioses. The research is being undertaken by the Centre for Plant-Microbe Symbioses supported by the Danish National Research Foundation.

Care of the environment, resources and consumer demands have increased the need for profitable plant production of high quality with low consumption of resources and reduced negative impact on the environment. Risø's research on plant production and ecology aims at achieving these goals. In line with the national strategy for agricultural research, Risø strives to meet the agricultural sector's needs for new biotechnological methods of plant processing. These are particularly in the areas of plant nutrient content, resistance to disease, effective fertiliser utilisation, biologically based methods of cultivation and the analysis of ecological risks from transgenic crops.

Risø is studying the effective utilisation of the natural interaction between plants and symbiotic microorganisms. In 1997, this research received an important contribution through a grant from the Danish National Research Foundation that has enabled the launching of a new programme in which the three important symbioses between plants and microorganisms are compared at the molecular level. During 1997, channels transporting nitrogen between a plant and a microorganism were identified and the transport of plant proteins between a plant and a microorganism was studied.

The environmental side-effects of fertilisation can also be decreased by better utilisation of the nitrogen in animal manure. Risø has therefore studied the breakdown of nitrogen from animal manure in ecologically cultivated clover pastures. Studies of the genetic background for the absorption of nutrients have demonstrated that there is a basis for searching for genetic differences between plant types.

In 1997, Risø's Environmental Risk Assessment Facility, RERAF, was commissioned and studies were made of the way in which the climate affects the plant uptake of carbon dioxide. Stable isotopes were used to demonstrate that mychorrhizal fungi make a significant contribution to the absorption of phosphorus by winter wheat in ecological cultivation systems.

Risø's research into plant breeding aims to provide more knowledge of the genetic background for the characteristics that determine the health and quality of agricultural crops. Much of Risø's work in 1997 was performed within the framework of the Cereals Network. This network has been established as a collaborative venture between the processing industry, plant breeders, the agricultural advisory service, sector research institutions and universities. The network is co-ordinated by the Danish Institute of Plant and Soil Science and aims to strengthen the collaboration between research and the production of cereals and cereal products. Among other areas, Risø is working on identifying DNA markers. These can be used to find, select and combine new genes in plants which affect, e.g. their resistance to disease, malting quality, oil quality and protein quality. To make it quicker and easier for plant breeders to select plant material for further selection, Risø is working on the production of genetic maps that identify the genes that give the plants the desired characteristics. The Danish oil seed rape breeding companies DLF-Trifolium and Danisco Seed have produced plants for a project at Risø in which markers have been developed for the rapid selection of plants. The results are being included in Risø's genetic map of the total genetic material in oil seed rape.

A number of projects within the Cereal Network's first framework programme aim to improve the levels of resistance to fungal diseases of Danish cultivates of barley and wheat. The goal is to identify cultivates that can be grown without the use of fungicides. Risø is working within the network's framework to increase resistance to the 12 most damaging leaf and seed-borne diseases in barley and wheat using DNA markers, epidemiological studies and statistical analyses.

Resistance to the costly barley powdery mildew disease is in many cultivates due to the very effective resistance gene mlo. Even if this gene is believed to influence malting quality negatively, cultivates have been developed that combines good malting characteristics with mlo resistance, e.g. the cultivate Alexis. Genetic analyses at Risø using DNA markers have demonstrated that the presence of the mlo gene in Alexis negatively affects malting quality. Through the selection of many other genes during the breeding process, however, it has been possible to compensate for this effect.

Another strategy for the control

Photo: Michael Fischer

A researcher prepares the gene-gun for firing. He is holding a membrane covered with gold particles coated with a genetic material.

of powdery mildew on barley is to identify the fungal genes, which are required for a successful infection. Knowledge of the biochemistry behind the infection will provide the scientific background for the design of targeted pesticides, which block specific pathogenic processes. Risø has isolated novel genes, which are expressed in the early stages of the interaction between fungus and plant. To examine the importance of these genes during fungal infection Risø is developing a transformation method for the powdery mildew fungus using particle gun acceleration. Researchers at Risø were the first to succeed in expressing foreign genes in the powdery mildew fungus and work is now concentrating on developing a stable transformation system where introduced genes are also expressed in the following generations.

Slurry pollutes the environment and there is a very great need to develop methods to reduce this form of pollution. This is the subject of another of the Cereals Network's focal areas, where Risø is working on increasing animal utilisation of the phosphorus and minerals in fodder and on reducing the environmental impact of phosphorus in slurry. Most of the phosphorus in grains of barley is compounded in the protein phytine, which also binds important minerals, thus leading to poorer utilisation of both phosphorus and minerals by the animals. Risø has now identified a number of mutants in barley that contain less phytine, making most of the phosphorus freely accessible so that it can be utilised by the animals. The mutants have been identified in the widely grown Alexis cultivate of malting barley. It is also possible to increase phosphorus utilisation through the over-production of the enzyme phytase in transgenic corn. The phytase breaks down the phytine in the fodder, thus releasing both phosphorus and minerals to give the same advantages in nutrition as low phytine mutants. The environmental benefits are great and a reduction of 20–30 % in the phosphorus pollution of pasture from slurry is within reach. Finally, the insertion of a heat-stable phytase can ensure that the enzyme can withstand the heat-processing to which ground corn is subjected during fodder production, e.g. due to processing to destroy salmonella bacteria. As an alternative to low phytine mutants, a transgenic strain of barley has been developed that produces so much microbial phytase that it can release the phytine-compounded phosphorus in the fodder.

Risø is continually working on risk assessment in connection with the spread of transgenes from genetically modified crops to related weeds. Results from 1997 have demonstrated that field mustard like plants (third back-crossed generation) with herbicide tolerance from oil seed rape do not have reduced vitality compared to wild field mustard.

In 1997, Risø has developed a promising method of analysis for surface-active chemicals from, for example, sulphur-based soaps in sewage sludge. Work on organic pollutants in sewage sludge will be further expanded through SMP-97 collaboration, in which Risø has the management responsibility for the Centre for Sustainable Land Use and Management of Contaminants, Carbon and Nitrogen.

Based on a large number of analyses, Risø has in 1997 achieved interesting results relating to the significance of methods of cultivation to the trace-element profile in vegetables. The final results will be published during 1998.

The plant production and ecology programme area is based in the Plant Biology and Biogeochemistry Department.

Key figures in 1997

In 1997 the department engaged 114.2 man-years, 30.9 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 68.9 million, 29.7 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.
COST · The Biotechnological Research Programme · The first framework programme of the Danish Cereal Network · SMP · EFP · ENVIRONMENT · EUREKA · EUROTRAC · FAIR · Sustainable Agriculture Research Programmes · Cultivated Plants of the Future · Research Centre of Organic Farming

FØTEK · Nordic Counsil of Ministers · NORDTEST · SJVF · STDI: Pesticide · The Danish Association of Organic Agriculture

Private companies, research institutions and others
Abedfonden · AFEAS (The association of freon manufacturers) · Alfred Jørgensens Laboratorium · AU · Carlsberg · Danisco Seeds · Danish Institute of Agricultural Sciences · DIA · DLF-Trifolium · DMU · DTI · DTU · Dæhnfeldt · Several institutes under the Advanced Technology Group and The Danish Agricultural Advisory Centre · Ford · FSL · GEUS · KU · KVL · Danish Veterinary and Food Administration · MST · NASA · NKT Holding · Pajbjergfonden · Rigshospitalet, Copenhagen, Denmark · Roskilde County Hospital · RUC · Sejet Plant Breeding · National Forest and Nature Agency · Danish Meat Research Institute · Danish Directorate for Development · Topsøe A/S · AAU ·

www.risoe.dk/pbk

Systems analysis

Photo: Aerospatiale

The Airbus 340 simulator at Aerospatiale, Toulouse, France. The pilots are wearing eye trackers during this experimental study of pilot behaviour during scenarios of abnormal take-offs. Risø was responsible for the experiment and subsequent analyses.

As industrial and energy systems become increasingly complex and increased emphasis is devoted to environmental considerations and human factors. Risø's research in systems analysis is directed towards these issues. It aims to cover the requirements of the chemical industry, process industry, transport industry, electrical utilities, authorities such as the Danish Energy Agency and the Danish Environmental Protection Agency, Danish consulting engineering companies and international organisations such as the EU and UNEP.

In order to provide the basis for better prioritisation of the future commercialisation of technologies, components, materials, etc., there is an increasing demand for guidance concerning future prospects including direct and indirect social consequences of the choices made. To address this need, Risø has in 1997 formulated and established a new programme dealing with technology scenarios. During 1997, a multi-disciplinary workgroup in the department formulated the initial description of this research field and established contacts with relevant companies, researchers and authorities. An advisory panel with 10 members has been established representing Danish industry and Danish and international research environments.

When planning the energy systems of the future, authorities and the energy sector face many changes and new challenges: liberalisation of the electrical industry, new environmental charges and the integration of renewable energy supplies and other new energy technologies. Risø is therefore working on improving the methods for analysing energy, environmental and financial factors in the medium to long-term perspective and to adapt new technologies to complex energy systems. Activities in 1997 included the development of energy and environment-related satellite models for use in connection with ADAM, the official Danish macroeconomic model. Several projects have been implemented to evaluate the use and adaptation of sustainable energy, including wind energy on a large scale in the Danish energy system. A Danida financed project for a master-plan for the use of wind energy in Egypt in the period up to 2030 was concluded. A project was implemented to define the external environmental factors of the Danish energy system, with wind energy as an example, is based on a method developed in an EU project with uniform definitions for 14 countries.

During 1997, work has also been undertaken to update and further develop the INDUS model, so that it can be used to extrapolate energy consumption and emissions for the most important industrial sectors in Denmark. This work is being performed together with the electrical utilities and the Danish Energy Agency. Another important activity in 1997 was the completion of the electricity power pool project supported by EFP. Finally, Risø has in 1997 collaborated with the Rambøll consulting engineering company to implement a project relating to the national economic benefits of gas storage.

Photo: Boye Koch

Risø has calculated the external environmental effects of wind, biogas and natural gas using a new EU methodology. An important parameter in the assessment is the valuation of CO_2. Personnel from the Systems Analysis Department are seen discussing some of the calculations.

Industrial process and control systems are becoming steadily more complex, which increases the need to develop methods to identify, present and correct possible errors before the systems break down, as breakdowns can have major financial, environmental and human consequences. Risø's research into industrial safety and reliability aims to develop methods for the analysis of these problems. In 1997, work has been performed on the development of new methods of support in error diagnosis. These methods have been tested at several places including the Hammlab simulator of the Halden Reactor project in Norway.

Hidden errors in process and control systems are a still unsolved problem under study at Risø. As part of the conclusion of a Ph.D. project, a new method for error analysis in control systems using functional modelling has been reported.

There has been an increased public demand for risk evaluation of new and existing industrial plants. To this end Risø is developing new methods for more precise risk evaluation that can be used by emergency services, the authorities and industry. In this area during 1997, Risø has worked on improving methods of risk evaluation in connection with the location and expansion of chemical plants. The project is being implemented in collaboration with planners in the counties and municipalities. Further, Risø has carried out research within the field of consequence modelling with special emphasis on chemical fires and dispersion calculations. Finally, during 1997, a number of risk analyses were performed for Danish companies and authorities for use in connection with regulation procedures.

In industry as well as on air and maritime traffic, safety is highly dependent on the optimal interaction between people and advanced technical systems. Risø is therefore developing new methods for

analysing this interaction in order to be able to establish concepts for the safe and effective handling of complex work tasks.

Safety in air and maritime traffic has become an important expanded work area for Risø, and in 1997 an analysis of traffic pilots' handling of critical take-off scenarios based on an Airbus 340 simulator in Toulouse was performed for Aerospatiale SA. As part of the SAFECO EU project under the leadership of DNV (Det Norske Veritas) for methods of maritime risk analysis, simulator experiments with human subjects have been performed at the Danish Maritime Institute (DMI) and a model for the simulation of a helmsman's control actions has been developed and implemented. Finally, in collaboration with DMI and the University of Texas,

Photo: Michael Fischer

Professor Ogunlade Davidson, Visiting Professor at the UNEP Centre and Co-Chair of Working Group III in the Intergovernmental Panel on Climate Change, IPCC, (left) Dr. John Turkson, UNEP Centre, (centre) and senior researcher Kirsten Halsnæs, Risø, (right) are seen here planning an IPCC workshop in Africa on the integrated assessment of climate change policies.

a questionnaire study (1,450 responses) among Danish shipping companies regarding sea-going mariners' attitudes to safety has been concluded.

Together with Danfoss and with support The Danish Research Council for the Humanities work was performed in 1997 to set up a concept for searching for and exchanging information via the Internet in industrial development environments.

During the year, negotiations have been held with the Danish National Research Foundation regarding the establishment of a Danish Centre for Human-Machine Interaction. The centre is expected to begin operation early 1998 and be managed by Risø, with close collaboration with DAIMI and the Institute for Information and Media Science at AAU. Other participants will be DTU, DMI and Danfoss.

The UNEP Collaborating Centre on Energy and Environment is contributing to international efforts to reduce the environmental effects of energy production. The centre is financed by UNEP, Danida and Risø. In 1997, the centre worked on capacity building projects in a number of developing countries. The international scientific advisory panel for the centre, with representatives from Africa, Asia, Latin America and international organisations held its third meeting in November 1997.

One of the dominant activities in 1997 has been the establishment of the methodical basis for the analysis of the costs of greenhouse-gas reductions in different sectors such as energy, transport, agriculture, forestry and industry, and establishing a framework for a cross-sectoral comparison of costs. Work has also been undertaken on the environmental and social aspects of deregulation of the electricity sector in selected developing countries, and on the implementation of capacity building projects in 15 countries in Africa, Asia, Latin America and Eastern Europe. Finally, the UNEP centre organised a workshop for the Intergovernmental Panel on Climate Change (IPCC) on the 'Social and Economic Impacts of Climate Change Mitigation'. The workshop was held at Risø in June 1997, with some 100 participants from around the world. In 1997, the centre fulfilled the goal of doubling its activities in relation to the 1993 level – one of the success criteria in the management performance contract with the Ministry of Research and Information Technology.

The systems analysis programme area is based in the Systems Analysis Department.

Key figures in 1997

In 1997 the department engaged 58.5 man years, 11.9 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 47.1 million, 28.6 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.
EFP (under the Danish Ministry of Environment and Energy) · EUREKA · EU's 4th framework programme · Nordic Council of Ministers · SMP

Companies and organisations
Aerospatiale · AFREPREN · AiT · Asian Development Bank · AU · Cired · Climate Change Secretariat · Danfoss · Danida · Statistics Denmark · Secretariat of the Danish Economic Council · DMI · DMU · DTU · Elkraft · Elsam · ENDA · ENS · EU · GEF · GTZ · IPCC · KU · LBNL · Maersk line · Scandline · MST · Novo Nordisk · RUC (Roskilde University Centre) · SEI · Sida · SMP · UNAM · UNDP · UNEP · University of Bath · World Bank · AAU

www.risoe.dk/sys

Wind energy and atmospheric processes

Photo: Boye Koch

Visualisation of airflow over a wind turbine blade using tufts.

The world's wind energy is a major resource that is being increasingly utilised. The International Energy Agency (IEA) expects that the installed wind generating capacity will double in the period from the close of 1996 to the end of the century. Risø's research into wind energy and atmospheric processes aims to advance the global utilisation of wind energy through the development of methods of designing, constructing, testing and positioning wind turbines, and for the determination of wind loads and wind resources. The programme area also covers methods for determining the dispersion, composition and effects of air pollution.

An important prerequisite for the global use of wind energy is the development and implementation of methods and models to predict wind resources and wind loads. This requires new knowledge of wind climatology, atmospheric flow and turbulence. This research was strengthened in 1997 by establishing the wind power meteorology research programme.

In 1997, Risø began collaboration with the American electricity utilities' research institute – EPRI – on the implementation of models for short-term prognoses of production from wind farms. These are being developed in an EU JOULE project under Risø's management. The Danish electricity utilities ELKRAFT and ELSAM and wind farms in the United Kingdom and Greece are also participating.

Risø's WAsP computer software is the world standard for estimating wind resources. More than 400 copies have now been sold in over 60 countries. The software is under continual development in co-operation with the Danish wind turbine industry and the international research community. A Windows version is expected to be ready in 1998.

The department carries out testing and certification of wind turbines for the industry on a commercial basis and is extensively involved in international standardisation. In 1997, the testing service expanded its accreditation and was one of the main forces in the creation of a European net work of test stations, MEASNET, that aims to ensure automatic European recognition of test results. The building of a new testing site for large wind turbines in western Jutland has continued, and the completion of construction and capacity expansion of the blade-testing centre in Sparkær marked an important milestone. Certification activities have shown an increasing turnover during 1997 and the positive development of this activity has resulted in, among other things, the accreditation by DANAK.

The development of concepts for electrical components for wind turbines, wind turbine regulation, connecting to the grid and the system integration of wind turbines form part of a new research programme established in 1997. A major activity has been the development of a pitch-regulated wind turbine with a variable rotational speed in collaboration with Vestas and ABB, and supported by the Danish Energy Agency. The first measurements at a test installation at Risø have demonstrated that the regulation quality has been greatly improved and that further production improvements require on-line optimisation.

With support from the EU JOULE programme, work has been performed on connecting wind turbines to weak electricity grids. Two new concepts have been developed that can contribute to expanding the areas where wind turbines can be profitably installed by reducing the costs of net-reinforcing.

Continuing innovation in the wind turbine industry requires ongoing work on the development of new wind turbine concepts and models for the analysis of performance, loads, design and optimisation of wind turbines. In 1997, Risø established a new research programme to cover these tasks. The theoretical basis for the production of a wind turbine blade with a 10 % improvement in power yield was established during the 1994–97 management performance contract with the Ministry of Research and Information Technology.

To ensure the rapid documentation of blade profiles for the construction of new wind turbine blades, Risø, with the support of the Danish Energy Agency, has developed advanced measuring and calculation methods. The measuring method has now been completed and documented and will be applied to the testing of a series of new profiles developed by Risø. The dynamic calculation model has been verified in connection with EU projects. This means that Risø has two different methods at its disposal that supplement one another well.

Most modern wind turbines are built with blades that stall at higher wind speeds in order to limit the power output. In certain cases, however, blades can experience self-excited vibrations and become dynamically unstable. In a research project co-financed by the Danish Energy Agency and the EU JOULE programme, the basis for the design of stall-regu-

Foto: Boye Koch

Inspection of blades for small wind turbines.

lated wind turbines has therefore been expanded to achieve maximum stability during stall. The results have been implemented in the HAWC aerolastic analysis programme so that the design parameters giving the greatest margin of stability can be selected for new wind turbine designs.

To preserve Denmark's leading international position in the wind energy area, Risø aims at strengthening its position as a leading European wind energy centre. During 1997, the winners of an architectural competition to design a new building for this centre were selected to be the architect firm of Nielsen, Nielsen & Nielsen. Efforts are now being made to obtain funding for the construction. Efforts are being made to strengthen Risø's influence in international research and development co-operation in the wind power area. Since 1997, Risø has been acting as the Danish Energy Agency's representative for Denmark in the IEA co-operation agreement regarding wind energy. Risø has been given the leading role in formulating the strategy and action plan for the IEA's wind energy activities over the next four years. The international consulting activities in the area of wind energy in 1997 included work within projects in India, Kazakhstan, Fiji, the Cook Islands, Tonga, Egypt, Cape Verde, Russia and the Czech Republic.

In collaboration with DMU and other national and international partners, several projects supported by the EU, NMR and SNF have concentrated on studying the exchange of greenhouse gases between the sea and atmosphere. This work has provided new knowledge of dispersion and exchange, as well as development of and improvements to a number of measuring techniques. In a number of projects the depositing of nitrogen compounds to the sea from the air is under investigation, particularly the chemical and physical composition of the compounds in the atmosphere and its significance with respect to exchanges with the surface of the sea.

In the case of a nuclear accident, it is important to be able to calculate the dispersion of radioactive materials for evacuation purposes. In 1997, Risø concluded part of the RODOS-2000 project that is to be implemented in the European countries in 2000. Risø has also worked with Denmark's Emergency Management Agency's equivalent system, called ARGOS-NT, which is used in Denmark, the Baltic countries and Poland.

Foto: Boye Koch

Measurement of the charges of the batteries for a PQ-controller. PQ-controllers consist of a power electronic unit and a battery bank. They are used to control the power flow from, for example, a wind turbine in order to minimise the impact of the wind turbine on the electricity grid.

During 1997, boundary layer measurements on Mars were made as part of the NASA Pathfinder mission. Risø, supported by the SNF, participated in the scientific group responsible for the recording and interpretation of these data. This study, which took place in a markedly different atmosphere from Earth, has confirmed the universal validity of a number of theoretical models.

The environmental effects of new compounds such as Freon alternatives have been studied, and for a group of these alternatives, the goal in the management performance contract with the Ministry of Research and Information Technology, i.e. the international dissemination of the results, has been fulfilled. Efforts in this area are continuing, and Risø's consultancy to Danish and international industry will continue.

The environmentally benign motor fuels of the future will contain oxygen. These new fuels designed for internal combustion engines have been studied along with new fuel additives in collaboration with the Ford Motor Company.

In collaboration with the University of North Carolina, it has been demonstrated that the content of nitro-naphthalenes is related to the mutagenic and carcinogenic properties of exhaust gases.

The wind energy and atmospheric processes programme area is based in the Wind Energy and Atmospheric Physics Department.

Key figures in 1997

In 1997 the department engaged 87.7 man-years, 9.1 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 74.4 million, 47.7 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.
EFP · EUREKA · EU's special programme for environmental research and development · Force · JOULE · MAST · Nordic Council of Ministers' Research Programme 1993-1997 · SMP · STVF · THERMIE · UVE

Companies and organisations
AAU · A/S Wincon · ABB · Bonus Energi A/S · Carl Bro A/S · CENELEC · COWI · Dahl Instruments · Danida · Danish Energy Agency · Danish Institute of Plant and Soil Science · Danish Standards Institute · Danservice · Danske Svineslagterier · Defu · DMI · DMU · DNV · DTI · DTU · Elkraft · Elsam · EPP (Greek electricity utility) · EPRI · EUREC-Agency · EWEA · Genvind Production · Hanstholm Møller · IEA R&D Wind · IEC, International Electrotechnical Commission · Kampsax · KU · LM Glasfiber A/S · Ministry of the Interior's Emergency Management Agency · MST · N.E.G. MICON A/S · The Great Belt Connections A/S · Svendborg Brakes A/S · UN · Vestas Wind Systems · Danish Veterinary and Food Administration · Windgineering · Windworld af 1997 A/S · World Bank

www.risoe.dk/amv

Nuclear safety

Risø is the only Danish research centre combining the fields of nuclear safety, radiation protection and development of nuclear measuring techniques. The research in this programme area addresses needs for consultancy on nuclear and radiation matters by governmental authorities. Risø participates in international treaty-defined collaboration in the environmental, radiation protection and reactor safety areas.

Denmark is surrounded by a number of countries with nuclear power stations. This means that there is a need for Danish professional expertise in the area of reactor safety that can advise Danish authorities and other institutions about issues related to nuclear power. Risø therefore participates in international collaboration on reactor safety.

During 1997, work has been performed on the so-called 'loss of coolant' accidents in water-cooled reactors that under certain conditions can give rise to unintended criticality. As part of a Nordic reactor safety project, Risø has developed a computer model that can simulate this type of accident. Work is continuing in an EU project (SARA) with Danish, Finnish and Swedish participants.

Within the Nordic collaboration on reactor safety, a literature study of core meltdown in boiling water reactors has been carried out. During recent years, the development of boiling water reactors has moved towards simpler systems using natural circulation of the cooling water instead of pumps. This may give rise to instability in the reactor. A computer system to study the stability of the new reactors has been developed and tested at Risø.

Risø has developed methods of calculation to determine the neutron irradiation doses and also the neutron activation of reactor components.

For the Swedish nuclear power station at Forsmark, calculations of the neutron doses in parts of the power station's reactors have been performed on a contract basis.

The many decommissioned Russian nuclear submarines lying in the naval bases on the Kola Peninsula that still have uranium fuel in their reactors have given rise to concern in the West. Risø has participated in an international study arranged by the North Atlantic Co-operation Council on the safety conditions for these reactors. The Danish effort has concentrated on criticality accidents and it has shown, among other things, that the risk of these potential accidents is greater than the Russians have previously assumed. This has contributed to the introduction of new safety measures in Russia.

Risø is involved in research and development in the field of radiation protection in order to be able to predict, determine and limit the doses that the population receives from man-made and natural sources of radiation.

The radioactive gas radon that is found everywhere in nature seeps into houses and increases the probability for developing lung cancer. In 1995–96, Risø studied a number of methods to reduce the radon concentration in Danish detached homes. It was demonstrated that active ventilation could remove up to 90% of the radon content of the air. The study, for which the final report was published in 1997, was financed by the National Building Agency and the SIS and was performed in collaboration with SIS, SBI, GEUS and the COWI consulting engineering company. In 1997, a project in collaboration with the Danish Geotechnical Institute was concluded in which radon measurements on intact soil columns were analysed. The results have helped explain why radon levels in Danish houses built on moraine clay are relatively high. Through these studies, Risø has fulfilled one of the goals in the management performance contract for 1994–97 with the Ministry of Research and Information Technology.

The Chernobyl accident showed that beta irradiation of the skin gave rise to many serious radiation injuries to emergency personnel and that there was a need for better methods and instruments for beta dosimetry. Risø has therefore developed equipment for this purpose. Risø's studies have demonstrated that so-called laser-scanning imaging plates can be used to determine the dose distribution in beta radiation fields on larger surfaces polluted by beta radioactivity. Another advanced instrument for beta dosimetry based on the energy spectrum of beta radiation is being developed as part of an EU project. Development of the equipment was completed in 1997, while the development of methods to convert the energy spectrum to beta doses will continue up to 1999.

Risø has prepared a handbook

Foto: Boye Koch

Risø has developed a technique for reconstructing radiation doses in an area affected by a nuclear accident using optically stimulated luminescence (OSL). During 1997, improvements have been made to the sensitivity of the measuring technique and the Risø-developed apparatus has been sold to many foreign laboratories.

on cleaning up radioactively polluted areas as part of the Nordic Nuclear Safety Research (NKS) collaboration. The handbook explains how it is possible in many cases to reduce the external radiation to the population in a contaminated area by a factor of 10 or more.

After a nuclear accident two key questions arise: What doses have the affected population received and what are the consequences of this exposure? Risø has developed a technique that can reconstruct the radiation doses. This is done by the use of so-called optically stimulated luminescence, OSL. The technique is based on collecting samples of bricks, porcelain, road paving and other items containing quartz and feldspar. These minerals store energy when they are exposed to radiation. OSL equipment can subsequently release the energy as a flash of light that can be measured by a photocell. It is then possible to calculate how much radiation the object being studied, and thus the population, have been exposed to as a result of the accident. During 1997, work has focused on fine-tuning the measuring technique and the equipment has been sold to many laboratories all over the world.

The former Soviet Union manufactured an important part of its nuclear weapons arsenal south of Ekaterinburg. It is now known that the Soviet authorities disregarded a number of environmental and safety precautions, which resulted in massive radioactive contamination of the environment. The international community is now assessing this pollution with a view to possible clean-up and Risø is participating in this work. As part of the EU financed SUCON (South Ural Contamination) project, it has been possible for the first time to demonstrate the presence of technetium-99 in Russian river sediments. If a method to identify technetium in such small concentrations can be further developed, this discovery will make it possible to trace the emissions arising from the 1950s right up to the Arctic Ocean.

Risø is participating in the IAEA's study of the radioactive pollution of the ocean environment at Mururoa and Fangataufa after the cessation of the French nuclear test program. During 1997, Risø has performed measurements of a number of samples that contain radioactive substances that derive from the atmospheric tests in the 60s and 70s. The results will be part of an international report that will be published by the IAEA in 1998.

When environmental impact is to be evaluated in an internationally comparable way, reference methods are needed to determine the basic elements of significance to the environment. Risø is developing such methods and, in 1997, the platinum contents in soil and air samples collected in the greater Copenhagen area and in the centre of the city were determined using neutron activation analysis in collaboration with Ben Gurion University, Israel, the Technical University in Munich and Denmark's National Environmental Research Institute. Analyses of mussel tissue for traces of platinum showed that the content was too low for an actual certification, but, precisely because of the special character of the neutron activation analysis Risø has been able to specify a definitive upper limit.

In collaboration with the National Institute of Occupational Health, certification analyses of human serum and urine samples were performed for SM&T in Brussels. An intercalibration for DSM Research in the Netherlands included determination of a number of elements in a polymer compound for subsequent certification.

Photo: Michael Fischer

Beta radiation unit for TL/OSL equipment.

The nuclear safety programme area is based in the Nuclear Safety Research and Facilities Department.

Key figures in 1997

In 1997 the department engaged 62.3 man years, 3.1 of which involved Ph.D. students and post docs. The departments financial turnover in 1997 was DKK 104.5 million, 37.5 million of which were derived from research contracts.

The department's sponsors and collaboration with private companies in 1997

Danish and foreign research programmes, etc.
Emergency Management Agency's East Programme · EU's 4th framework programme · FØTEK · KAS (Copenhagen County Hospital), Herlev · Danish Environmental Protection Agency's AMAP programme · NATO · NKS · SIS · SNF

Private companies
COWI · Danish exporters of foodstuffs (e.g. Kløvermælk) · Delta Lys og Optik · Forsmark Kraftgrupp AB

www.risoe.dk/nuk

Board of Governors and Management

Board of Governors

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From September, 1997

Jørgen Elikofer, Head of Department
Danish Metalworkers' Union
From September, 1997

Per Buch Andreasen, M.D., Dr. Med.Sc.
Copenhagen University Hospital
From September, 1997

Birthe Skands, Development Manager
Carlsberg A/S
From December, 1997

Jens Olsson, Research Technician
Risø National Laboratory
Elected by Risø's personnel

Adjunct Professor
Kurt Nørgaard Clausen, Ph.D.,
Head of Programme
Risø National Laboratory
Elected by Risø's personnel

Erik Lindegaard, Director
Danish Environmental Protection
Agency
Until August, 1997

Trade Union Representive
Bjarne Weiler Madsen
Danish Metalworkers' Union
Until May, 1997

Professor Søren Molin
Laboratory of Microbiology
The Technical University of Denmark
Until August, 1997

John Hebo Nielsen, director, Ph.D.
Gaia Technologies A/S
Until November, 1997

Photo: Boye Koch

Secretariat of the Board

Lisbeth Grønberg,
Acting Vice Director, LL.M.
Risø National Laboratory

Poul Mohr, LL.M.
Risø National Laboratory

Organisation

Management
Jørgen Kjems, Ph.D., Managing Director from October 1, 1997, Vice Director until September 30, 1997
Hans Bjerrum Møller, Dr.Phil., Managing Director until September 30, 1997
Lisbeth Grønberg, LL.M., Acting Vice Director from October 1, 1997

Management Secretariat
Flemming Øster, Ph.D.
Acting from October 1, 1997
Lisbeth Grønberg, LL.M.
Acting Vice Director from
October 1, 1997

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Science Journalist
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Erik Kristensen, B.Sc.

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Birgit Pedersen, Librarian RLS

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Minna Nielsen, M.A.

Nuclear Safety Research and Facilities Department
Benny Majborn, Ph.D.

Wind Energy and Atmospheric Physics Department
Erik Lundtang Petersen, Ph.D.

Systems Analysis Department
Hans Larsen, Ph.D.

Plant Biology and Biogeochemistry Department
Arne Jensen, M.Sc.

Condensed Matter Physics and Chemistry Department
Professor Klaus Bechgaard, Ph.D.

Materials Research Department
Niels Hansen, Dr.Techn.

Optics and Fluid Dynamics Department
Adj. professor, Lars Lading, M.E.

*Established February 1, 1998. Formerly the Safety Department.

Education of scientists and others

In 1997, a total of 73 Ph.D. students, equivalent to 61 man years, have carried out their research projects at Risø. Of these, 50 have held a research scholarship co-financed by the Danish Research Academy and Risø, while five were financed by the Engineering Science Centre and 18 by other means. The number of post-doctoral research scholarships has increased from 51 in 1996 to 62 in 1997, equivalent to 40 and 52 man-years respectively, of which 26 are foreign research scholars. The pilot program in collaboration with the Danish Academy of Technical Sciences' Committee on Industrial Ph.D.s with industrial post-doctoral projects has led to a total of four completed and three discontinued projects, while additional three projects were started in 1997.

The Optics and Fluid Dynamics Department's work in non-linear dynamics is a central part of the newly created graduate school initiative – known as the Danish Graduate School in Non-linear Science – together with MIDIT and DTU. NBI, HCØ, KU and Novo Nordisk are also participants in this graduate school. The graduate school is sponsored by the Danish Research Academy. Through this special education, the students become acquainted with the leading international experts participating as guest professors and also interact with ongoing research through participation in symposia and other activities. Foreign Ph.D. students visit the school for shorter periods and participate in its activities. This year, 12 overseas guest professors and eight overseas Ph.D. students participated.

The following were awarded Ph.D. degrees in 1997

Materials Research Department
Henrik Christoffersen, M.Sc., KU
Torben V. Rasmussen, M.E., DTU
Bjørn Clausen, M.E., DTU
Torben K. Jacobsen, M.E., DTU
Chris Pickup, M.A. (Cantab.), University of Cambridge, UK
Nini H. Pryds, M.E., DTU

Condensed Matter Physics and Chemistry Department
Michael Gerstenberg, M.E., KU
Morten Jagd Christensen, M.E., KU
Martin Vigild, M.E., DTU
Marianne Pedersen, M.E., DTU

Optics and Fluid Dynamics Department
Niels Chr. Rømer Holme, M.Sc., NBI

Plant Biology and Biogeochemistry Department
Trine Møgelberg, M.Sc., KU
Frank Jacobsen, M.Sc., RUC
Christian Helweg, M.E., RUC
Merete Bilde, M.Sc., KU
Finn Jørgensen, M.Sc., KVL
Annette Behrens, M.E., DTU
Lars Landbo, M.Sc., AAU

Systems Analysis Department
Hans Henrik Krogh Andersen, M.Sc. (Pysch.), RUC
Christina Ingerslev, M.Sc., RUC
Kirsten Halsnæs, M.Pol.Sc., RUC
Atoosa Jalashgar, M.E., DTU

Wind Energy and Atmospheric Physics Department
Liselotte S. Geernaert, M.E., KU

Nuclear Safety Research and Facilities Department
Niels Agersnap Larsen, M.Sc., NBI
Ayoe Gry Hoff, M.Sc., NBI
Martin H. Grosell, M.Sc., KU
Kendra Foltz, B.Sc., University of Illinois

The following have been awarded doctorates in 1997

Erik Steen Jensen, Ph.D., of the Plant Biology and Biogeochemistry Department, has been awarded the title of Doctor of Agricultural Science for a doctorate thesis on the Role of Grain Legume N_2 Fixation in the Nitrogen Cycling of Temperate Cropping Systems.

Dorte Juul Jensen, Programme Manager, of the Materials Research Department, has been awarded the title of Doctor of Technical Sciences for a doctorate thesis on Orientation Aspects of Growth during Recrystallisation.

The following have been appointed adjunct professors

Gunnar Gissel Nielsen, Dr. Agric. Sc., of the Plant Biology and Biogeochemistry Department, has been appointed as an adjunct professor at the Royal Veterinary and Agricultural University for a five-year period.

Ole John Nielsen, Ph.D., of the Plant Biology and Biogeochemistry Department, has been appointed as an adjunct professor at Roskilde University Centre for a five-year period.

Prizes

Professor Klaus Bechgaard, M.Sc., Head of Materials Physics and Chemistry Department, has been awarded the NKT researcher prize for 1997.

Education

As part of the efforts to strengthen university contacts, facilities for distance learning have been established in a joint initiative for remote education and video-conferences between the natural science faculties of the country's six universities, the Royal Veterinary and Agricultural University and the Materials Research Department. The Danish National Centre for Technology Supported Learning, the Ministry of Education and the participating institutions are financing the initiative. This modern form of communication was commissioned by the Minister of Education on 15 May 1997. Apart from the remote education of students, the equipment will be used for training courses for employees of Danish companies and for meetings and conferences with national and international partners.

To motivate the young generations to engage in higher education in natural and technical science, Risø arranges a number of activities for the senior classes at lower secondary schools, for upper secondary school classes and for their teachers. The Risø Visitor Centre thus in 1997 hosted 38 8th–10th classes in its 'Researcher for a Day' arrangements, as well as 23 classes from upper secondary schools and technical schools. During 1997, the Materials Research Department hosted 47 students from upper secondary school for a 1-day experimental course and 15 students for a 2-day course in materials research.

The Nuclear Safety Research and Facilities Department contributes to education in radiation instrumentation and health physics at the Technical University of Denmark (DTU). This collaboration is being expanded to include reactor physics and nuclear power techniques. Every year in January, a number of students from DTU go through a practical course on the DR1 educational reactor. In addition in 1997 DR1 hosted about 40 upper secondary school classes that went through training courses on the reactor.

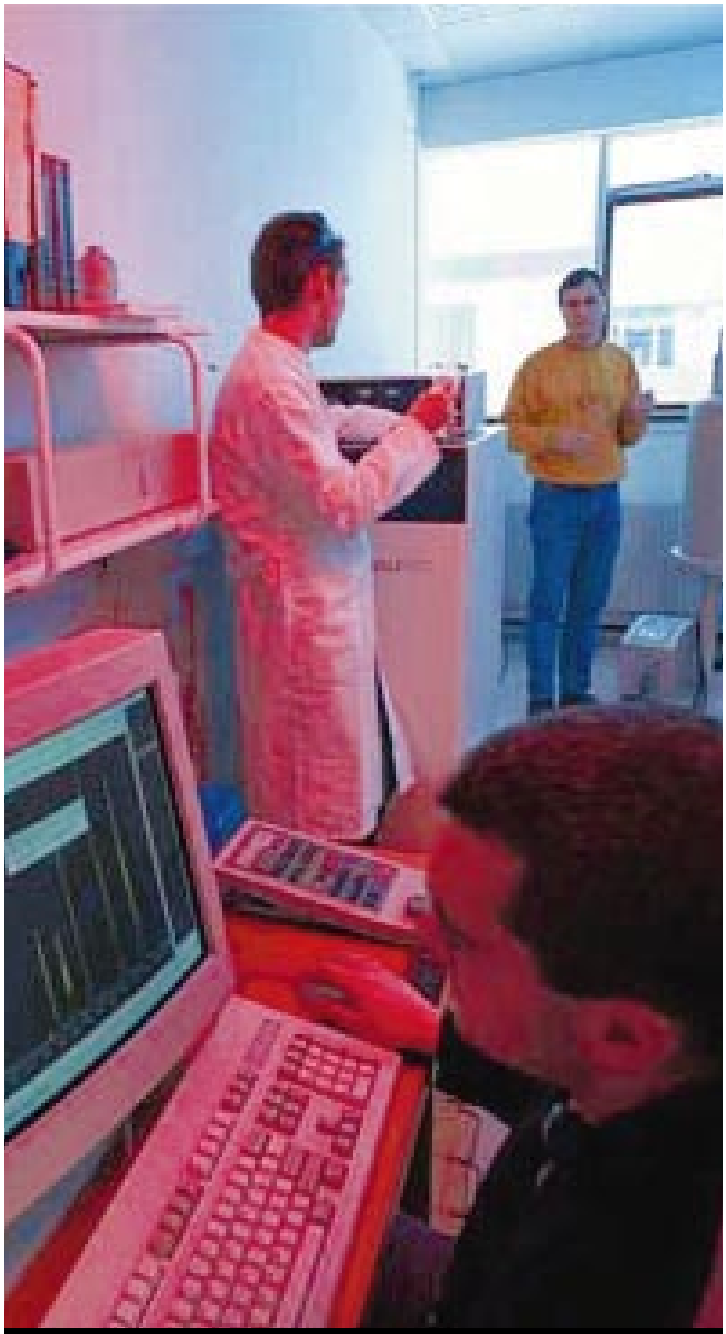


Photo: Boye Koch

Characterisation of organic compounds and polymers by NMR spectroscopy using the 250 MHz NMR spectrometer at the Condensed Matter Physics and Chemistry Department.

Risø's publication and lecture activities

One of Risø's important goals is the dissemination of its results to the research community through articles in international journals, research reports and other publications.

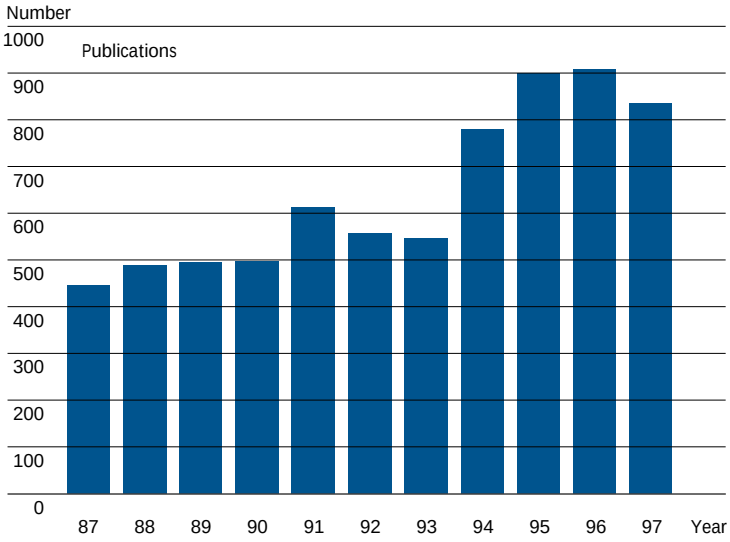


Figure 1. Risø's total annual publication activities in the period 1987–97.

Figure 1

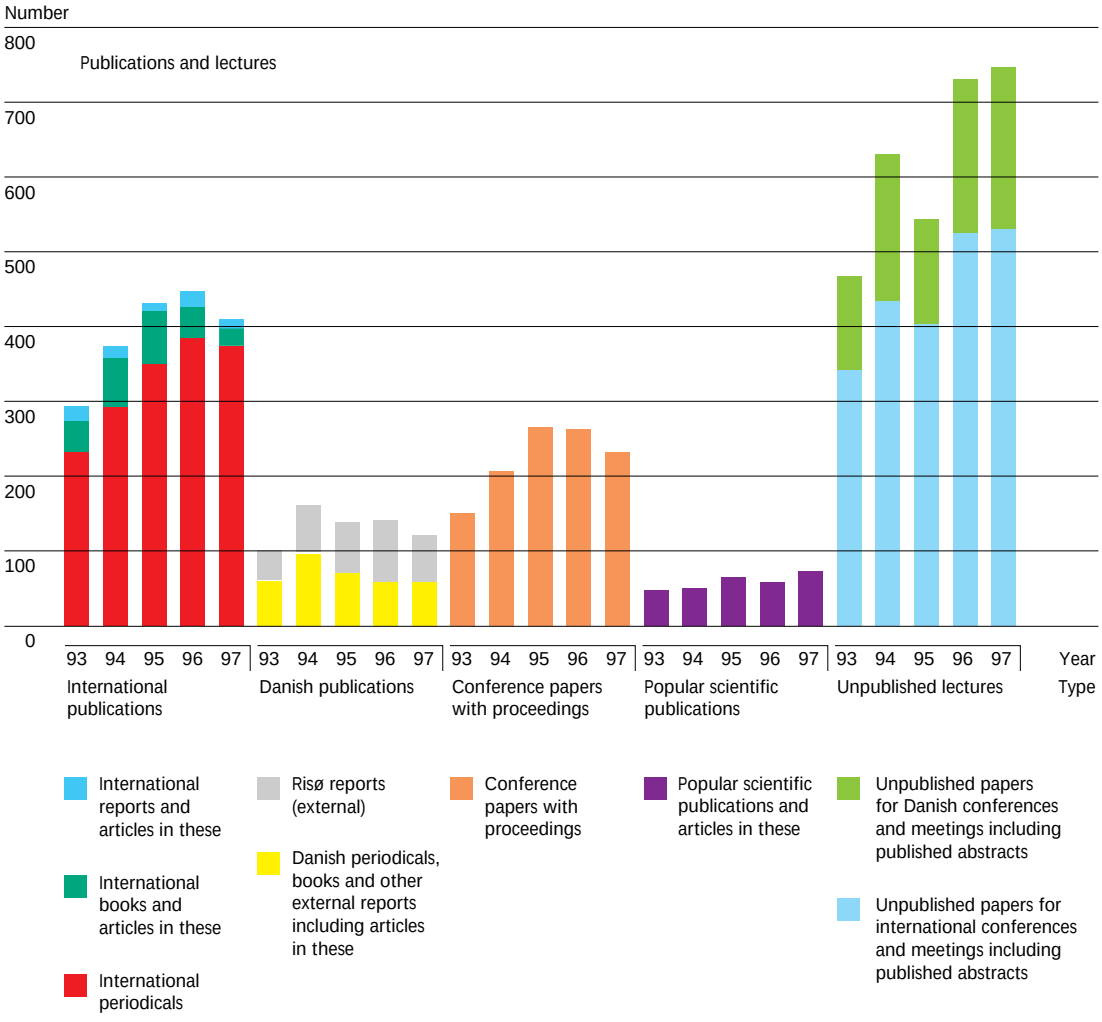


Figure 2. Number and distribution of Risø's publications in the period 1993–97 and number of unpublished lectures in the same period.

Figure 2

Risø's articles in ISI source journals in the period 1982–96

The information systems of the Institute for Scientific Information, ISI, are the most widely used for bibliometric analyses. ISI indexes more than 4,000 international journals in the field of the natural and technical sciences, and approx. 3,000 journals in the arts and social sciences (ISI Source Journals). In addition to indexing these journals, the ISI also counts the number of times a given article has been mentioned in other authors' reference lists (citations).

Risø subscribes to ISI's institutional citation report – ICR – and thus has a database with references to the articles in ISI's Source Journals in which Risø is given as the author's address. In addition to providing information on the number of times that Risø's articles have been cited, the database also provides information on how often the articles 'should' have been cited, i.e. the so-called expected number of citations. ISI calculates the number of expected citations by taking the average number of references to articles of the same type and in the same journal over an extended number of years. The database thus gives Risø the opportunity to see whether the institution's articles are cited more or less frequently than can be expected.

The ICR database documents that Risø's articles in the period 1992–96 has been cited 45% more than expected.

Comparison of the number of publications in the five-year period 1992–96 and the number of publications in the two preceding five-year periods shows that the number of articles from Risø in ISI's Source Journals is increasing (Figure 3).

Not only has the number of citations increased (Figure 4), but there has also been an increase in the average number of citations per article (Figure 3). In order to be able to compare the three five-year periods, only the number of citations made during the period in which the relevant articles were published has been calculated.

The database also makes it possible to illuminate Risø's collaboration with other research institutions. 24% of the 1,414 articles that ISI indexed in the period 1992–96 that has Risø authors were published together with other researchers from Denmark. The five foreign countries with which Risø has jointly published most frequently are the USA (17%), Germany (12%), the United Kingdom (8.9%), Sweden (5.3%) and France (5.3%).

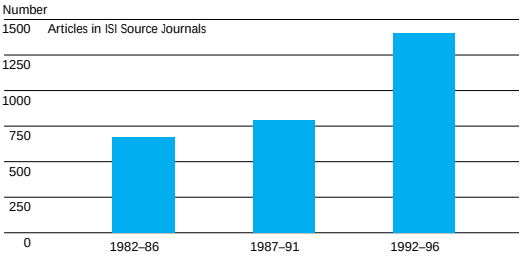


Figure 3

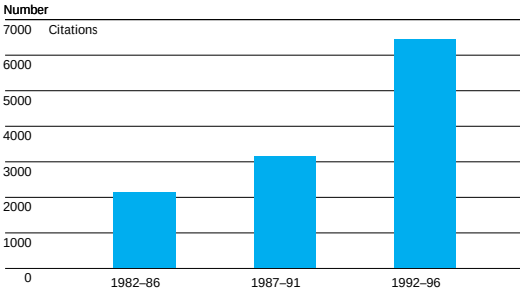


Figure 4

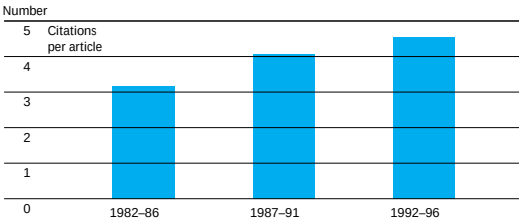


Figure 5

Institutions with which Risø has published the largest number of articles	Number of articles
Technical University of Denmark	80
University of Copenhagen	60
Ford Motor Co.	51
Danish National Environmental Research Inst	32
University of Minnesota	29
University of Oxford	29
The Royal Veterinary & Agricultural University	27
KFA Jülich Gmbh	26
Russian Academy of Science	26
Aarhus University	24
AT&T Bell Labs	24
Oak Ridge National Laboratory	24
Weizmann Institute of Science	22
Swedish University of Agricultural Science	17
University of Mainz	16
University of Uppsala	16
Rutherford Appleton Laboratory	15
Brookhaven National Laboratory	13
Chalmers University of Technology	13
European Synchrotron Radiation Facility	13
Panum Institute	13
University of British Columbia	12
University of Hamburg	12
Institute Laue-Langevin	11
University of Amsterdam	11
Delft University of Technology	10
Desy	10
Hahn Meitner Institut Berlin Gmbh	10
Jagiellonian University	10
Max Planck Institut für Festkörperforschung	10

Figure 6

Figure 3. Risø's articles in ISI Source Journals in the period 1982–96, specified in five-year periods.

Figure 4. Number of citations from Risø's articles in ISI Source Journals specified for the same five-year periods within which the articles were published.

Figure 5. Average number of citations per Risø article specified for the same five-year periods within which the articles were published.

Figure 6. Institutions with which Risø has jointly published ten or more articles in the period 1992–96 (ISI Source Journals).

Green Account

In 1996, the Board of Management decided to introduce environmental management beginning January 1, 1997. This is the second time that Risø has produced its Green Account.

Risø's Green Account contains information on the consumption of resources such as water, electricity, heating, natural gas and coolants, as well as information on emissions in the form of emissions to the air, sewage, sewage sludge and waste. The impact on employees in the form working accidents and radiation doses is also included. The Green Account also includes documentation of Risø's ability to comply with legislation using several legal means such as injunctions.

Environmental staticstics for Risø National Laboratory	Environmental key-figures 1996	1997	Risø 1997	Limit or *typical values* [a]
Injunctions, etc.				
Injunctions from the environmental authorities	0	0		
Petitions from the environmental authorities	0	0		
Injunctions from the Labour Inspection Service	4	0		
Guidances from the Labour Inspection Service	1	2		
Instances of exceeding limit values for sewage	1	0		
Violations of 'Conditions for operating nuclear facilities'	7	0		
Special reports on the nuclear facilities	0	1		
Risks				
Accidents reported	23	18		
Injuries treated in Risø's emergency room	111	78		
Industrial accidents reported to the Labour Inspection Service	9	3	3 per [b]	*9 per 1,000* [c]
Industrial accidents reported to Occupational Injuries Agency	3	1		
Maximum individual effective dose [d] (mSv)	9.1	7.5	7.5 mSv	20 mSv [e]
Overall annual effective dose [f] (man-mSv)	253.0	167.6		
Consumption				
Water consumption (m^3)	72,555 [g]	59,276	59 m^3/PE	*62 m^3/PE* [h]
Power usage (MWh)	14,150	11,962 [i]	105 kWh/m^2 [j]	83 kWh/m^2 [k]
Heating (MWh)	17,244	12,776 [i]	162 kWh/m^2	190 kWh/m^2 [m]
Natural gas [n] (m^3)	1,823,885	1,862,998		
Coolants [o] (kg)	281	353		
Atmospheric emissions				
Argon (GBq)	23,000	23,000		
Tritium (GBq)	21,000	3,500	0.7 µSv/year [p]	200 µSv/year [q]
Iodine (GBq)	0.0077	0.0035		
Radioactive carbon dioxide (^{14}C emissions) from bitumen facility (GBq)	8	6		
Particular ß activity from destillation facility (GBq)	0.00036	0.00018		
Sewage, etc.				
Sewage (m^3)	61,400	48,900	48,900 m^3	182,500 m^3 [r]
Chemical oxygen demand, COD (kg)	3,438	1,535	31.4 mg/l	
Biochemical oxygen demand, Bl_5 (kg)	878	196	4.0 –	15 mg/l
Suspended state (kg)	890	342	7.0 –	20 –
Total nitrogen (kg)	1,019	377	7.7 – [s]	6 –
Total phosphorus (kg)	190	176	3.6 –	
pH		8.0	8.0	6.5-8.5
Sediments (ml/l)		0.1	0.1 ml/l	0.5 ml/l [t]
Heavy metals [u] (kg)	10.8	9.5		
of which zink (kg)	9.5	8.5	174 µg/l	1,000 µg/l
Unspecified ß activity in treated sewage [v] (GBq)	0.100	0.064	0.0013 Bq/ml	0.15 Bq/ml
Tritium with distilled active sewage (GBq)	3,700	3,800		
Tritium in secondary cooling water from DR 3 (GBq)	480	33	2.1 kBq/ml	370 kBq/ml
Sewage sludge				
Quantity of sludge (tons)	6	6		
Heavy metals [w] (g)	17,900	14,500		
of which Mercury (g)	94	61	10 mg/kg	*0.8 mg/kg* [x]
Cadmium (g)	55	31	5 –	*0.8* – [x]
Nickel (g)	286	12	2 –	*30* – [x]
Lead (g)	471	520	85 –	*120* – [x]
Copper (g)	5,180	2,300	375 –	*1,000* – [x]
Zink (g)	8,050	5,570	910 –	*4,000* – [x]
Waste				
Waste to be disposed of outside Risø (tons)	182	166		
of which chemical waste [y] (tons)	4	10		
Waste for recycling (tons)	28	67		
Waste for disposal at Risø (tons)	8	7		
Low-activity waste from Risø [z] (tons)	4	3		
Low-activity waste from Danish customers [z] (tons)	6	3		

Risø's impact levels are specified for 1996 and 1997. Limit values or typical reference values are specified so that Risø's levels can be evaluated in relation to these. Errors in the 1996 annual report in regard to water and sewage sludge have been corrected. For the water, electricity and heating areas changed 'accounting principles' have been applied. The figures for 1996 and 1997 therefore cannot be directly compared.

Risø has complied with all injunctions, etc., from the authorities in 1996 and 1997. Risø consider violations very seriously and has implemented measures to reduce incidences of violations in the future. The results of these were successful in 1997.

The number of occupational accidents and injuries treated at Risø's emergency room is lower in 1997 compared to 1996.

Risø's operation of nuclear facilites makes it a unique institution in Denmark. As can be seen from the Green Account, the impact from this area is far below the 'permitted' values.

It can be seen from the figures that Risø's consumption of heating and electricity is high in relation to the comparative values.

During 1996, reconstruction of Risø's sewage treatment plant to include the removal of nitrogen was started. The reconstruction occurred partly due to the authorities' heightened requirements for sewage purification. After a start-up period, the final emission requirements took effect on January 1, 1997. In spite of the start-up problems in the removal of nitrogen, Risø was just able to comply with the regulation of nitrogen. All other regulations were complied without any problems.

The concentrations of heavy metals in Risø's sewage sludge exceed the permitted levels for sludge to be spread on agricultural land. Risø's sludge is therefore not used for this purpose and is instead deposited at a controlled disposal facility.

In an overall view Risø has in 1997 reached the goals stated in Risø's policy for purchasing environmetally sound products. This applied to the goals set for paper, computers and research instruments. Regarding computers, the goal was that 85 % of the purchased computers should apply to Risø's environmentally sound products guidelines. Actually, 70 % of the purchased computers applied to the guidelines, while the rest has been bought through other channels than Risø's framework agreement.

Occupationally exposed workers

Dose interval (mSv)	1996	1997
0.00– 0.19	66	66
0.20– 0.50	60	80
0.51– 1.00	31	25
1.01– 2.00	28	30
2.01– 3.00	15	7
3.01– 4.00	17	1
4.01– 5.00	4	4
5.01– 6.00	2	3
6.01– 7.00	1	1
7.01– 8.00	2	3
8.01– 9.00	2	
9.01–10.00	1	
Total	**229**	**220**

Collective effective doses, excl. tritium, in 1996 and 1997. Dosimeters with non-recorded doses are not included. The limit value is 20 mSv/year. Over 90 % of the doses are lower than 10 % of the limit value.

Notes

a Wherever Risø's endorsements specify limit values, these are noted. In certain fields there are no limit values. In some fields, values that are characteristic for equivalent areas/fields have been found and shown with italic letters.

b Per 1,000 man years.

c Per 1,000 employees in research and development in natural science and techniques. For teaching and research as a whole: 10 accidents/1,000 employees. Source: reported industrial accidents, annual report 1996; National Institute of Occupational Health report no. 2.

d Maximal individual effective dose. The individual effective dose is defined as the sum of the equivalent doses to each separate organ multiplied with their respective tissue weight factor for the individual employee. The maximal individual effective dose corresponds to the maximal dose to an individual employee.

e Radiation protection: in the area of radiation protection, dose-limitation principles are applied. These state that doses from exposure to radiation at work should be kept as low as reasonably achievable and that doses must not exceed the dose limits set by the governmental authorities. Effective dose: 20 mSv/year.

f The collective dose of Risø's employees is defined as the sum of the individual doses received by all persons (effective doses).

g The figure for 1996 has been changed since Risø's Annual Report for 1996. This is because the consumption of water in the last Annual Report included consumption by DMU, NBI and CAT. In 1996, these institutions consumed 8,165 m^3.

h Roskilde municipal's sewage plan, 1988.

i In contrast to previous years, Risø's electric power consumption in 1997 is calculated exclusive of losses in the transformer station.

j DR 3's and RERAF's electric power consumptions are not included, as these power consumptions are unique to Risø.

k The average electricity consumption by area for education and research. For offices the consumption is 57 kWh/m^2 (The Danish Energy Agency).

l In contrast to previous years, Risø's consumption of heating for 1997 is calculated exclusive of heat losses in pipes.

m The average consumption of heat for education and research. For offices the heating consumption is 109 kWh/m^2 (The Danish Energy Agency).

n The major part of the natural gas was used to produce heat and electricity for Risø, DMU and the other institutions on Risø's grounds.

o Account of consumption of fully and partially halogenised hydrocarbons used for cooling purposes. A small portion of this is used for research purposes. In 1997, approx. 300 kg Freon 22 was used.

p Doses of tritium, argon and iodine are summary doses at the perimeter fence.

q The maximum contribution from each source is suggested by various government authorities to be between 100 and 300 mSv/year.

r The limit value is estimated from the amount of sewage, which is allowed to discharge per 24 hours under dry weather conditions.

s The average concentration of nitrogen exceeds the limit value. However, this does not give rise to actual non-compliance, as consideration must be given to the spread of the analysis results.

t Guidelines for the amount of sediments after two hours.

u The content of the heavy metals which Risø analyses in sewage. Analysis is performed for cadmium, lead, copper, uranium and zinc. Metals with a density beyond 5 g/cm^3 are considered as heavy metals.

v Unspecified ß activity: Total activity for unspecified in terms of isotopes.

w The content of heavy metals, which Risø analyses in the sludge: chrome, nickel, copper, zinc, cadmium, mercury, lead, uranium, lanthanum, praseodymium and thorium. The method of making estimation has been changed compared to the 1996 annual report and the 1996 figures have been corrected accordingly. Previously strontium was included in the estimate.

x The limit values for the heavy metal content of sludge applies if the sludge is to be spread on land to be used for agricultural purposes. Risø's sludge is not currently used for this purpose, but is disposed of at a controlled disposal facility.

y In recent years chemical stocks at Risø have been cleared out. This explains why the quantity of chemicals sent to the municipal disposal facility for chemicals is still higher than normal.

z Low-active waste deposited temporarily at Risø derives from Risø's own activities as well as from all over Denmark since Risø is obliged to receive disposed radioactive isotopes. Low-activity waste is defined as radioactive waste for which the dose rate at a distance of 1 m from the surface of the waste container does not exceed 5 mSv/h.

Finances

Operating statements for the state institution Risø	Accounts 1996	Accounts 1997	Budget 1998 *	Noter
DKK million at current prices (excluding VAT)				
Government appropriations for operating, plant and equipment costs	253.0	260.1	264.9	
Contracts earnings	207.4	222.1	238.5	
Total income	460.4	482.2	503.4	
Wages and salaries	280.0	278.6	289.9	
Other operating costs	146.0	162.7	178.5	
Investments	47.3	23.1	54.6	1
Total expenses	473.3	464.4	523.0	
Result (to be carried forward)	–12.9	17.8	–19.6	2

* Revised per April, 1998

Notes:

1 Of which DKK 21.6 million were plant and equipment expenses in the National Accounts in 1997.

2 The state institution Risø's net value was written down in 1996 by an extraordinary amount of DKK 30 million (from DKK 44.8 million to DKK 14.8 million) as a result of a budget adjustment from the Ministry of Finance.

Percentage distribution of expenses 1997

Salaries 60,0%

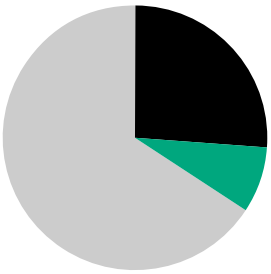
Purchases of goods and services 23,7%

Acquisition of equipment 5,3%

Sundry operating expenses 6,2%

Investments 4,7%

Distribution of expenses 1997 by area

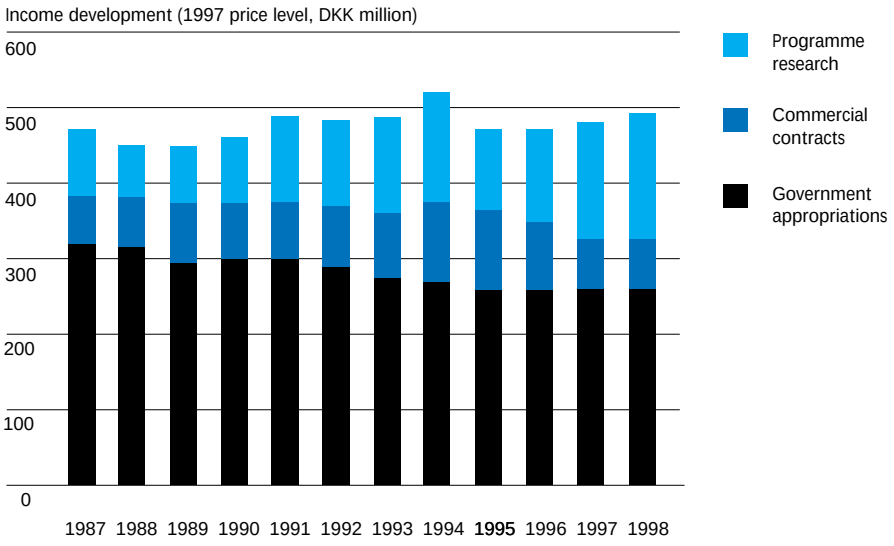


Research 66,0%

Technical and administrative functions 26,

DR3 and the Isotope Laboratory 7,9%

Income development



Balance sheet at the end of December	Accounts 1996	Accounts 1997	Notes
DKK million at current prices (excluding VAT)			
Assets			
Tangible fixed assets	222.4	233.0	1
Current assets:			
– Liquid holdings	1.2	1.2	
– Accounts receivable	92.3	105.4	2
Total assets	315.9	339.6	
Liabilities			
State financing of Risø's activities			
– State financing of plant and equipment	222.4	233.0	
– Accumulated result from operations	1.9	19.7	
– State financing of other assets	67.9	57.1	
Short-term debt	23.8	29.8	
Total liabilities	315.9	339.6	

Notes:

1 The book value of fixed assets at the end of 1997. The amount is an accumulation of acquisitions and construction through the years reduced by the value of depreciation. 5 % of the accumulated balance is depreciated using the straight-line method according to the Budget Guidelines. In comparison, Risø's property was valued at DKK 369.5 million in the official property valuation in 1996. Machines, fixtures and fittings are usually not included in fixed assets' book values.

2 Of which costs met to be invoiced in the following financial year (EU projects, etc.):

Accounts 1996	Accounts 1997
19,1	29,8

Development in personnel 1990–97	1990	1991	1992	1993	1994	1995	1996	1997
Academic staff	308	305	319	345	357	355	360	342
Technical/administrative staff	574	524	515	499	488	476	455	417
Ph.D. and post docs	41	37	55	65	73	96	104	104
Students and trainees	51	48	51	47	46	44	41	36
Total staff (man years)	974	914	940	956	964	971	960	899

Acronyms and other abbreviations

AAU Aarhus University
AFREPREN The African Energy Policy Research Network
AIT Asian Institute of Technology
ATV The Danish Academy of Technical Sciences
AU Aalborg University
BRITE Basic Research in Industrial Technology for Europe. An EU research programme.
CAT Centre for Advanced Technology. Science park established jointly by Risø, RUC and DTU.
CENELEC The European Committee for Electrotechnical Standardization
CIRED Centre International de Recherche sur l'Environnement et le Développement
CO_2 Carbon dioxide. A gas produced by burning fossil fuels. CO_2 belongs to the group of gases contributing to the greenhouse effect.
DEFU The research institute of the Danish electrical utilities
DMI The Danish Meteorological Institute
DMI The Danish Maritime Institute
DMU The National Environmental Research Institute
DTI The Danish Technological Institute
DTU The Technical University of Denmark
EFP The energy research programme of the Danish Ministry of Environment and Energy
ELKRAFT An electrical utility group on the Danish island of Zealand
ELSAM An electrical utility group for the Danish mainland, Jutland, and the island of Funen.
ENDA Environmental Development Action in the Third World
ENS The Danish Energy Agency
ESPRIT European Strategic Programme for Research and Development in Information Technology. An EU research programme (DGXIII).
ESRF The European Synchrotron Radiation Facility
EUCLID European Cooperation for the Long Term in Defence. An EU research programme.
EURAM European Research in Advanced Materials. An EU research programme.
EURATOM The European Atomic Energy Community
EUREKA The European Research Coordination Agency
FØTEK 2 The Danish food technology research and development programme
GEF The World Bank's Global Environmental Facility
GEUS The Geological Survey of Denmark & Greenland
GTZ Deutsche Gesellschaft für Technische Zusammenarbeit. A German support programme to implement the UNFCCC.
HCØ The H.C. Ørsted Institute
IAEA The International Atomic Energy Agency
IEC The International Electrotechnical Committee
INTAS The International Association for the Promotion of Co-operation with Scientists from the new independent states of the former Soviet Union
IPCC The Intergovernmental Panel on Climate Change
ITER The International Thermonuclear Experimental Reactor
IVC Engineering Science Centre
JOULE Joint Opportunities for Unconventional or Long-term Energy Supply, the EU energy research programme on non-nuclear energy and efficient exploitation of energy
KU The University of Copenhagen
KVL The Royal Veterinary and Agricultural University
LBNL The Lawrence Berkeley National Laboratory
LIP Large Installations Programme
LIS New Lasers, Integrated optics and ultra-fast Switching.
MAST Marine Science and Technology Programme. An EU programme.
MATE. Multi-Aircraft Training Environment.
MIDIT Center for modelling, non-linear dynamics and irreversible thermodynamics.
MST The Danish Environmental Protection Agency
MUP The Danish Materials Technology Programme
MW Megawatt. 1 million watts.
NAA Neutron activation analysis
NBI The Niels Bohr Institute
NKS Nordic Nuclear Safety Research A Nordic committee with participants from government authorities, research institutes and companies involved in nuclear power
NKT A Danish company
RITA Re-invented triple axis
RUC Roskilde University Centre
SANS Small-angle neutron scattering. Equipment for studying radiation damage in metals, polymers and biotechnological materials, for example. With special low-energy neutrons, the equipment enables materials with larger atomic distances to be studied.
SBI The Danish Building Research Institute
SEI The Stockholm Environment Institute
SIDA The Swedish International Development Co-operation Agency.
SIS The Danish Institute of Radiation Hygiene.
SMP The Danish Strategic Environmental Research Programme
SNF The Danish Natural Science Research Council
SOFC Solid oxide fuel cell. Fuel cells made of ceramic materials.
STVF Danish Council for Scientific and Industrial Research
THERMIE The EU demonstration programme for non-nuclear energy
THOR Technology by Highly Oriented Research. The Ministry of Research and Information Technology's new THOR programme.
UNAM Universidad Nacional Autonoma de Mexico
UNDP United Nations Development Programme – a UN development agency.
UNEP United Nations Environment Programme – the UN environmental programme.
UVE The Danish programme for the development of sustainable energy
WAsP Wind Atlas Analysis and Application Program, developed at Risø.

RISØ

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